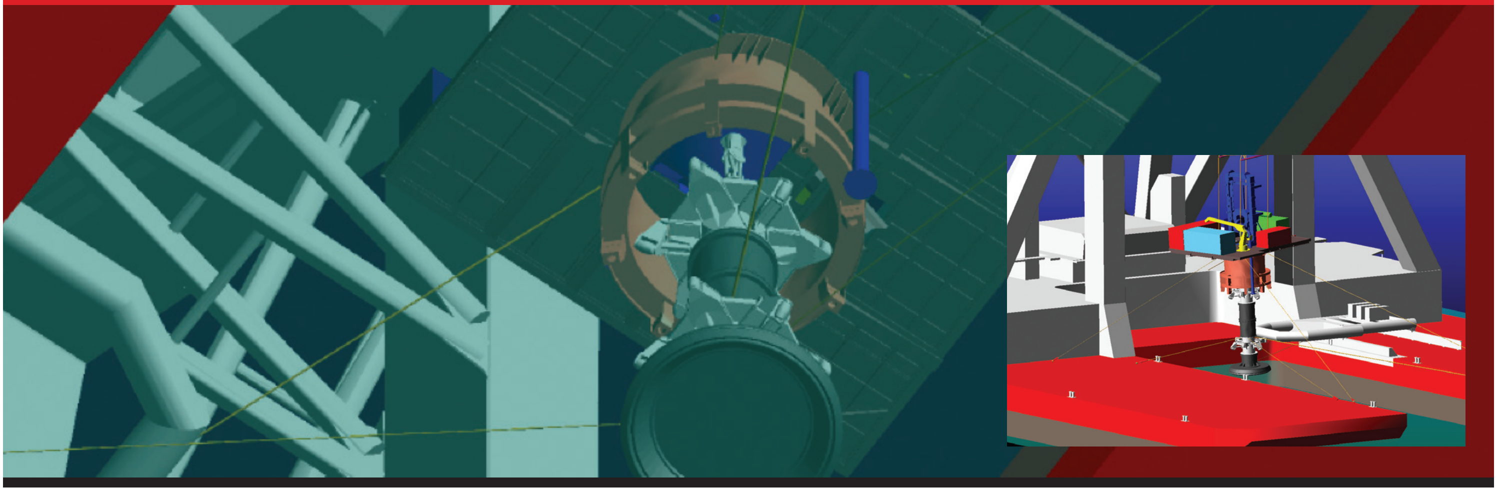
MSC Software

CASE STUDY

MSC Software: Case Study - Knud E. Hansen A/S

Safe Marine Operations in Wind Energy

Dynamic Motion Analysis for Wind Farm Drilling Rig Transport Operation



Anholt Offshore Wind Farm

The Anholt Offshore Wind Farm is a Danish wind farm currently under construction, located in Kattegat, between Djursland and Anholt Island. The project was initially commissioned by DONG Energy with an estimated total cost of 10 billion Danish kroner.

In March 2011 DONG Energy sold 50% of the Anholt Offshore Wind Farm to PensionDanmark and PKA, with shares of 30% and 20% respectively.

The Biggest Offshore Wind Farm in Denmark

By its completion date, which is expected to take place between 2012 and 2013, the wind farm will have capacity of 400 MW providing electricity sufficient to meet approximately 4% of Denmark's total electricity consumption. As a result, it will become the biggest offshore wind farm in Denmark.

Wind Farm Construction Challenges

111 wind turbines of 3.6 MW each will be supplied by Siemens Wind Power and placed on locations with water depths between 15 and 19 m. The required foundations and installation have been contracted to the Danish company MT Højgaard A/S.

The foundations consist of monopiles with a diameter of approximately 5m and a wall thickness of 50-90 mm driven into the seabed. Their length is usually adjusted to the specific location and varies from 37m to 54m. By means of a large hydraulic hammer, the monopiles are driven between 18m to 36m into the seabed depending on water depth and seabed conditions. The heavy monopiles weigh up to 460 tons. If the monopile runs into boulders below the seabed, the boulders will be removed by a Drill Rig.

The Drill Rig is supplied by MT Højgaard A/S and transported from the storage location to the drill site using the installation vessel HLV SVANEN. The Drill Rig needs to be sea

Key Highlights:

Industry

Offshore & Wind

Challenge

Accurate assessment of complex mechanical systems that require a dynamic analysis

MSC Software Solutions

Adams

Benefits

- Innovative approach to study marine & offshore structures interfaces
- Ensure the safety of the marine operations
- Reduce risks and costs of the wind turbines installation
- Anholt offshore windfarm to become the biggest offshore windfarm in Denmark

"Adams Software helped us to understand the motion and forces involved by capturing the full gamut of real world complexities including rigid bodies, flexible bodies, springs, dampers, joints and all others mechanical components. The software never placed any limits on what I wanted simulated, yet it made it possible to assemble the complex model very quickly. "

Mirco Zoia, Navel Architect & Offshore Eng., Knud E. Hansen A/S

fastened onboard the HLV SVANEN during the transport and also when HLV SVANEN needs to seek shelter due to adverse weather. For operational and safety reasons the Drill Rig can only be transported or deployed in waves of significant height up to 1.0m.

Knud E. Hansen A/S (KEH) was contracted by MT Højgaard A/S to assess the Drill Rig's waves induced motion while transported by HLV SVANEN, and to calculate the maximum tensions on the lashing cables for a maximum operational wave height of Hs_o=1.0m.

Multibody Dynamics Simulation Provides More Accurate Modeling

For the Drill Rig motion analysis, MSC Software's Adams was used. Adams is the most widely used solution for motion assessment of multi-bodies. Adams helps to study the dynamics of moving parts, how loads and forces are distributed throughout mechanical systems and to improve and optimize the performance of the design. Adams can easily simulate the reality of a complex multi-body system in motion.

Mr. Zoia, the KEH Naval Architect who performed the study said: "Adams Software helped us to understand the motion and forces involved by capturing the full gamut of real world complexities including rigid bodies, flexible bodies, springs, dampers, joints and all others mechanical components. The software never placed any limits on what I wanted simulated, yet it made it possible to assemble the complex model very quickly. Every part of the construction could be visualized during the simulation and the plots of the results easily shown. All the wave motions have been easily applied to the dynamic system in order to study the dynamic behavior in detail while ensuring the safety of the marine operations and reducing the risks and costs of the installation of this wind farm".

Methodology

Initially, the 3D Multi-body Dynamic model of the system composed by HLV SVANEN, the Drill Rig and its crane lifting components (Lifting Spreaders, Lifting and Lashing Equipment), was created in a CAD software and then imported to Adams. Densities and other material properties were given to the parts of the 3D Model. All the parts in motion were joined together with translation, revolving, spherical and cylindrical joints to simulate as close as possible the real behaviour of the system. The steel and fibre ropes of the system were defined as flexible dynamic bodies with the same material properties (density, young's modulus, poisson's ratio, and damping coefficient) as the actual ropes. The winch pretensions were defined using preloaded spring-dampers. Motions, constraints, wind forces and winch pretension loads were then applied to HLV SVANEN. The motion analysis was based on the HLV SVANEN maximum response motion previously assessed.

The dynamic analysis was carried out to assess the maximum displacement of the Drill Rig, and the minimum required winch pulling force to fulfill the requirements of the client and to safely carry out the necessary marine operations. The full 3D Dynamic Model is shown in Fig.1-3.

Marine Rules and Safety Factor

The dynamic analysis was performed in accordance with DNV Rules for Planning and Execution of Marine Operations. According to these rules, an Alpha Factor α=0.85 was used. The Alpha Factor defines the safety margin of the marine operations.

For example, an Alpha Factor α=0.85 means that for a design wave height Hsd=1.00m, the maximum allowed operational wave height shall be Hs_o=1.00*0.85=0.85m.

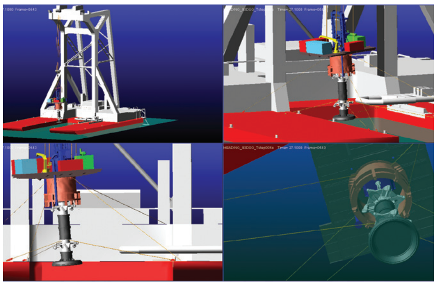


Fig. 1: Adams 3D Dynamic Model

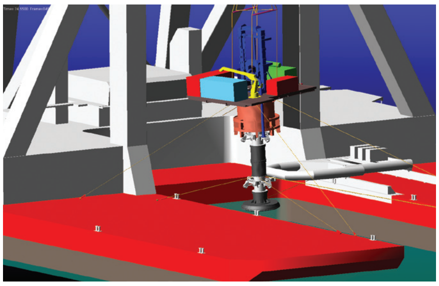


Fig.2 - Adams 3D Dynamic Model

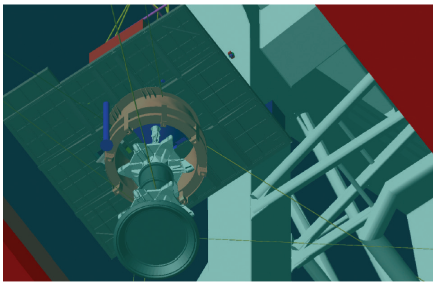


Fig.3: Adams 3D Dynamic Model

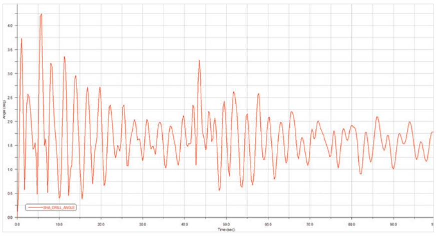


Fig.4 – Plot of the maximum angles between the Drill Extension and the BHA DR as function of time

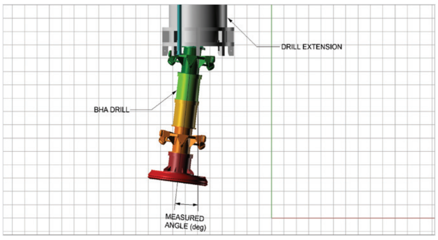


Fig.5 – Angle between Drill Extension and BHA DR

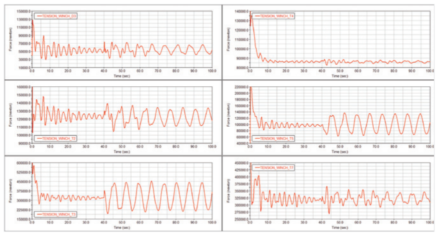


Fig.6 – Plots of the tensions of the winch cables as function of time

Maximum Allowable Displacement and Cable Tensions

For this study, the minimum requirements to fulfil were:

- To prevent damage to the lashed items and to the winches, the tension on the lashing cables to not exceed the maximum brake capacity (MBP) of the winches and ropes.
- To prevent collisions between parts and to safely carry out the marine operations, sufficient clearance to be checked between the Drilling Rig and HLV SVANEN structure and/or items on its deck.
- The angle between Drill Extension and BHA Drill Rig to not exceed the maximum allowed value of 6.8 deg.

Operational Motion Conditions

For this study the following two cases has been considered:

1. Drill Rig Transported to the Monopiles Installation Site in Wind and Waves.

- JONSWAP spectrum
- Significant wave height Hs=1.18m (maximum allowed operational wave height Hso=Hs*α=1.00m with α= alfa factor=0.85)
- Wave Period 5s<Ts<7s
- Water depth 15m and 28m
- Headings 0, 45, 90 deg.
- WIND Force 15m/s

2. Drill Rig in Shelter Area with Strong Wind Only.

- WIND Force 63m/s
- Headings 0, 45, 90 deg.
- No wave motion of HLV SVANEN was considered for this condition, as HLV SVANEN will be in a sheltered area and exposed to strong wind only.

Results for transport of drill rig in wind and waves, heading 90 deg. (worst operational condition)

The results of the maximum angle between the Drill Extension and the Bottom Hole Assembly of Drilling Rig (BHA DR) for heading of 90 deg. (worst operational condition) are shown on plot of Fig.4. The angle is defined as shown in Fig.5.

The tensions of the six winches and two fixed points lashing cables required to keep the DR in position, within the max allowable angle DR Extension-BHA DR, are respectively shown in Fig.6 and Fig.7. Name and position of the lashing cables are shown in Fig.8.

NOTE: A delay of 40 sec was given to the dynamic system in order to find its gravitational "quasi-static" equilibrium position (as very small oscillations will be always present) before initializing the motion. During this period of time the necessary pretension will be applied to the cables by the winches and the system will oscillate to find its "quasi-static" equilibrium.

The results for the worst operational condition (heading of 90 deg.) show that the lashing arrangement for the sea fastening of the Drill Rig onboard the installation vessel HLV SVANEN, during transportation, for a maximum operational wave height of Hso=1.0m, and exposed to wind of 15m/s, is efficient enough to safely carry out the required marine operations:

- Tensions on the lashing cables do not exceed the maximum brake capacity (BP) of the winches.
- No collisions between parts and sufficient clearance between the Drilling Rig and HLV SVANEN structure and/or items on its deck is ensured to safely carry out the required marine operations.
- The angle between Drill Extension and BHA Drill Rig does not exceed maximum allowed values.
- Indication of the pretension loads to apply to the winches for keeping the DR in position, within the max allowable DR Extension-BHA DR angle, is displayed in Table 1.

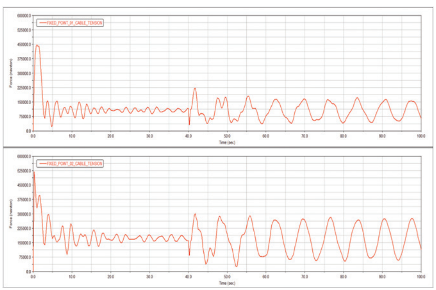


Fig.7 – Plots of the tensions of the fixed point cables as function of time

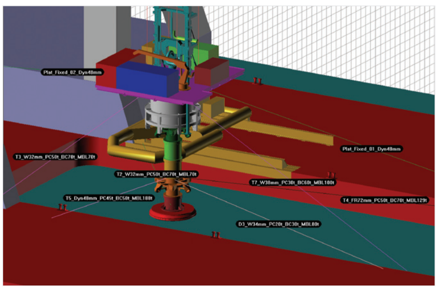


Fig.8 - Name and position of the lashing cables

CONDITION ONE – TRANSPORT OF DRILL RIG IN WIND AND WAVES HEADING 90 DEG.					
MEASURMENT (In steady motion condition)				MAX VALUE	
DR MAX TOT DISPL.				0.57m	
DR-BHA MAX ANGLE				1.99deg	
DR-TENSION OF THE WINCH CABLES	INITIAL PRETENSION FORCE				
	WINCH D3	51993N	5.30T	65727N	6.7T
	WINCH T2	122625N	12.50T	133416N	13.6T
	WINCH T3	318825N	32.50T	441450N	45.0T
	WINCH T4	85347N	8.70T	87309N	8.9T
	WINCH T5	96138N	9.80T	133416N	13.6T
	WINCH T7	316863N	32.30T	346293N	35.3T
DR-TENSION OF THE FIXED CABLES	CABLE 1	0N	0.00T	154017N	15.7T
	CABLE 2	0N	0.00T	272718N	27.8T

Table 1. Results for Heading of 90deg.

About MSC Software

MSC Software is one of the ten original software companies and the worldwide leader in multidiscipline simulation. As a trusted partner, MSC Software helps companies improve quality, save time and reduce costs associated with design and test of manufactured products. Academic institutions, researchers, and students employ MSC technology to expand individual knowledge as well as expand the horizon of simulation. MSC Software employs 1,000 professionals in 20 countries. For additional information about MSC Software's products and services, please visit www.mscsoftware.com.

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About Adams

Multibody Dynamics Simulation

Adams is the most widely used multibody dynamics and motion analysis software in the world. Adams helps engineers to study the dynamics of moving parts, how loads and forces are distributed throughout mechanical systems, and to improve and optimize the performance of their products.

Traditional "build and test" design methods are expensive, time consuming, and impossible to do sometimes. CAD-based tools help to evaluate things like interference between parts, and basic kinematic motion, but neglect the true physics-based dynamics of complex mechanical systems. FEA is suited for studying linear vibration and transient dynamics, but inefficient at analyzing large rotations and other highly nonlinear motion of full mechanical systems.

Adams multibody dynamics software enables engineers to easily create and test virtual prototypes of mechanical systems in a fraction of the time and cost required for physical build and test. Unlike most CAD embedded tools, Adams incorporates real physics by simultaneously solving equations for kinematics, statics, quasi-statics, and dynamics.

Utilizing multibody dynamics solution technology, Adams runs nonlinear dynamics in a fraction of the time required by FEA solutions. Loads and forces computed by Adams simulations improve the accuracy of FEA by providing better assessment of how they vary throughout a full range of motion and operating environments.

Optional modules available with Adams allow users to integrate mechanical components, pneumatics, hydraulics, electronics, and control systems technologies to build and test virtual prototypes that accurately account for the interactions between these subsystems.

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