General DOTC Project information

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Project title	*Bolt & Beautiful (B&B)*
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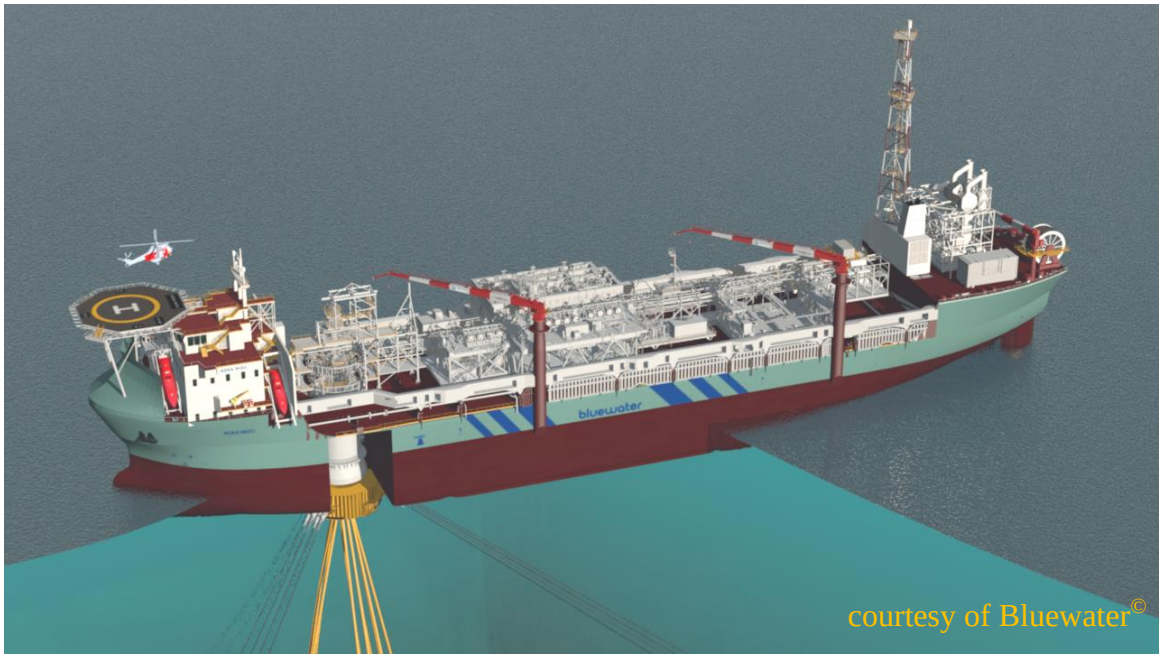
DOTC Program Line	*Green Performance and Smart Mega Structures*

1. Problem statement/ description

There are many applications of bolted connections in the offshore construction market. One of the applications is found in offshore wind, where the turbine supporting structure is connected to its foundation pile by means of a bolted ring flange. Another application is found in FPSOs, that weathervane around their turrets using bearings that are connected with a fair amount of large bolts. Bolts used in this application can be size M72, and their amount can rise up to over one hundred per flange.

In order to monitor the health of these connections, regular inspection is needed, requiring either operational downtime or costly support vessel time and maintenance procedures.



Is there a way to reduce the necessary inspections and to simplify the inspection and maintenance tasks involved?

Can we suggest a competitive – yet reliable – scheme of inspections and predict an adequate time to renew parts of the connection (eg. the bolts)?

What improvements can be made on either the ring flange design or its manufacturing tolerances to reduce the probability of failure?

2. Objectives, scope and desired results

One way to reduce the amount of inspections can be achieved by constructing a digital copy of the bolted ring flange connection used offshore, including the stresses applied to it whilst offshore, and to mimic its lifetime onshore (digital twinning). Measurements on the digital twin will determine and justify the necessary inspections offshore, making these stem from an accessible replica exposed to comparable loads.

Another way to reduce the amount of inspections can be achieved by receiving accurate and reliable live data of the relevant parameters from the offshore connection. This will require sensors installed on the real flange, potentially directly on the bolts. If these sensor data are transmitted to shore, the inspection scheme can be based on *the value of real data*, instead of aimed at *collecting the data*.

For both suggestions above, it will be necessary to have a realistic model of the bolted ring flange connection that takes into account all parameters that have an influence on the lifetime of the connection as a whole. Potentially, this may have to include parameters that determine the health of the bolt in particular.

The objective of this project is to validate existing bolted ring flange connection models, in order to advise on the parameters to measure offshore, how to quantify and/or qualify these parameters, as well as the risks derived from their value for the lifetime of the flange connection.

3. State-of-the art

Currently, the knowledge on causes for bolt failure is insufficient in order to predict or avoid this from happening. Degradation mechanisms that are thought to influence the bolt's fatigue endurance are corrosion, fluctuating loading, variance in the preloading of consecutive bolts, losing of pretension force in bolts, and fabrication imperfections or misalignments in the components of the connection. Due to the high amount of factors affecting the lifetime of the bolt, current practice is to inspect the bolts on a regular basis using the same tooling as used during the installation, to measure whether the preloading is still in place.

One of the latest developments has been the launch of bolts with an integrated measurement system, which would be a first step into remotely monitoring the health of the connection.

The B&B project will contribute to the state-of-the-art:

1. by advising on the critical parameters and their tolerances for a healthy bolted connection; This will be achieved by building a realistic model of the bolted connection, and analyzing what parameters are crucial to its degradation.
2. by improving the stress measurement technology to allow calibration of batches of bolts, which is necessary to apply the digital twin concept to the bolted connection;
3. by further developing acoustic sensing methodology to detect the early stages of degradation and apply this in a permanent health monitoring system.

4. Approach, activities and planning

The following approach is a suggestion:

- Development of a numerical parameterized bolted ring flange connection model in which the following can be varied: fabrication imperfections of the flange parts, geometrical misalignments of connection parts, preload sequence and offsets in preloading, effects of coating, and external loading effects;
- Investigation of an active ultrasonic method to measure bolt stresses without (or with limited) calibration;
- Investigation of a passive ultrasonic method (acoustic emissions) to measure fatigue damage and estimate pretension forces in the bolt connection.
- Determination of a bolted ring flange connection's fatigue strength as a whole, based on the achieved characteristics of separate components (bolts and ring flanges).
- Exploration of alternative connection designs that avoid the failure prone elements of the bolted ring-flange connection;
- Investigation of readily available mitigating measures for degradation , to increase the lifetime of a bolted connection.

DOTC expects the duration of this project to be in the order of three or four years.
In cooperation with our project partners, the above suggestion can be fine-tuned or re-focused. The planning will then be agreed in close consultation, once the approach has been confirmed.

5. Project partners

Being a DOTC project, the TU Delft and TNO will cooperatively work on this subject.
We will be looking for industrial partners to join us in this initiative! Please let us know your specific application and interest regarding bolted ring-flange connections, and send it to: dotc@dotc.eu