D O T C

Dutch Ocean Technology Centre

*Version 0.2: 15th February 2020*

## General DOTC Project information

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| Date | *2020-02-15* |
| Version | 0.2 |
| Project title | *BOLT & Beautiful (B&B)* |
| Project Team | *Dr. Ir. Richard Pijpers, Dr. Ir. Paula van Lieshout, Dr. Ir. Pooria Pahlavan, Prof. Dr. Milan Veljkovic, Dr. Ir. Henk den Besten* |
| Potential Stakeholders | *<parter 2>*<br>*<partner 3>*<br>*<partner n>* |
| DOTC Program Line | *Green Performance and Smart Mega Structures* |

## 1. Problem statement/ description

As a result of a growing market demand for larger capacity offshore wind turbines installed in deeper waters, the turbine supporting structures are expected to increase in size. Typically, these offshore foundations consist of a monopile connected to a transition piece with a bolted ring flange connection. Bolts used in this application are already as large as size M72, therefore an increased dimension of the flanges will primarily increase the amount of bolts. In order to monitor the health of this connection, regular inspection is needed, requiring costly vessel time and maintenance procedures. Wind farms are continuously placed further offshore, increasing the vessel time to reach them, and the inspection time on location increases due to a continuously growing amount of bolts.

*Is there a way to reduce the necessary inspection visits 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 support structure or the bolts in the connection?*

*Are there any improvements to make 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 vessel visits can be achieved by constructing a digital copy of the bolted ring flange connection used offshore, including the stresses applying 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 vessel visits 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 offshore flange, potentially directly on the bolts. This will lead to an inspection scheme based on *the value of real data*, instead of aimed at *collecting the data*.
For both suggestions above, it is 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 degradation mechanisms of the bolts 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 failures is insufficient in order to predict or avoid these events 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 during the installation to measure whether the preloading is still in place. With this current practice, the lifetime of the bolted connection is 25 years, but it is unclear what needs to be done to prolong this lifetime.

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 aims to contribute as follows:

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 methodology to allow calibration of batches of bolts, which is necessary to apply the digital twin concept to the bolted connection;
3. by developing acoustic 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 suggested:

- 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 connection;
- Investigation of readily available mitigating measures for degradation , to increase the lifetime of a bolted connection.

The planning that is foreseen for the activities involved:

***[TBD in cooperation with project partners]***

Total duration project is expected to be in the order of three/four years.

## 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 connections, and send it to:

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