

# DHRTC Technology Conference 2021

## Book of abstracts

Programme: Structural Integrity and Lifetime Evaluation

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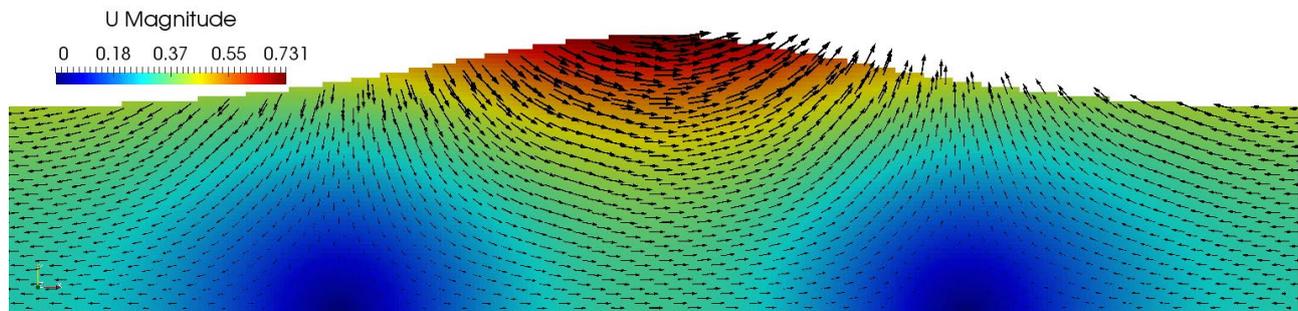
## Direct Surface Description for free surface flows in the OpenFOAM CFD library

*Jesper Roland Kjærgaard Qvist, Erik Damgaard Christensen*

Accurate prediction of wave loads from extreme waves on offshore jacket structures are important to ensure the structural integrity. Failure of a single element may lead to a total collapse of the entire structure, which makes it important to predict the local wave load distributions on each structural element.

The local wave load distribution on a structural element depends on the wave kinematics, and since the largest velocities are found at the wave crest, it is important to have an accurate prediction of the surface elevation and the velocities.

We have introduced a new solution algorithm in the open-source CFD code OpenFOAM that only models the flow in water and apply appropriate boundary conditions at the free surface. The resulting wave kinematics and wave propagation is accurate and the behavior of our model is in line with the underlying physics. The improved performance of our model is shown in a test case with a propagating solitary wave.



## **Finite Element Updating and Strain Estimation in Wind Turbine Tower**

*Sandro D. R. Amador, Rune Brincker and Meds G. Petersen*

*Department of Civil and Environment Engineering, Denmark Technical University*

When performing dynamic analysis of civil engineering structures using real vibration measurements it is crucial to create and update an FE model of the structure being analyzed. When it comes to FE model updating, two distinct categories of approaches exist to improve the accuracy of the FE model based on experimental results, namely the sensitivity and the perturbation-based techniques. This poster summarizes the FE model updating of a wind Turbine Tower carried out with a sensitivity-based technique and utilizing the dynamic properties estimated from vibration measurements acquired over the course of an ongoing structural health monitoring campaign. Once updated, model is used to estimate the strains by making use of an expansion technique, so that strain response histories due environmental excitation can be estimated at any degree of freedom of the modelled wind turbine. In order to assess the accuracy of the estimated strain histories, they are compared to the strains measured on the real structure.

## **Experimental investigation for the fatigue performance of the welded joints in offshore structures**

*Weijian Wu, Alexander Michel, Iman Shakeri, Martin Alexander Eder, Jacob Paamand Waldbjørn*

Welded joints are widely used in offshore structures. High stress ranges arise in the joints due to the local stress concentration under the fatigue loading. Moreover, initial flaws and welding induced high residual stresses exist in the welded joints. Currently, fatigue design and maintenance of welded joints are key parameters controlling the service life of the offshore structures. To have a better understanding of the fatigue performance of these welded joints, a series of experiments are carried out. In total, three levels of testing are performed. Single edge notch bending specimens are tested with different boundary conditions. Representative welded joints in offshore structures are loaded under various loading and boundary conditions. One full-scale K-joint is evaluated using the hybrid simulation technology. Non-destructive testing and beach marking techniques are applied in the tests to investigate the fatigue crack initiation and propagation behaviour.

## **Nonlinear damage identification of a single degree of freedom system with frictional constraint under shock**

*Amirali Sadeqi, Rune Brincker and Sandro D. R. Amador*

*Department of Civil and Environment Engineering, Denmark Technical University*

One of the nonlinear phenomena in civil and mechanical structures is energy dissipation and hysteresis. Contact in loose connections, torsional mode cracks, etc., are susceptible sources of frictional motion that lead to this phenomenon. This poster summarizes the dynamic analysis performed on a single degree of freedom system with additive elastic-frictional constraint. The system consists of a horizontal mass, spring, and damper attached by dry friction and vertical force to a parallel secondary system constituted by a mass and a spring. The performed analysis aims to simulate the response of such a system under horizontal shock/overload conditions, where the nonlinearity is activated and observable within only a short period. Then, the nonlinear response data is employed in the nonlinear identification process, and the nonlinear behavior is investigated as a damage source. To this end, the differential equations coupled only due to the velocity component are solved, and the measured response is taken into the direct linear and nonlinear parameter estimation scheme. The effect of stiffness, friction, and loading is also studied in the presence of noise contaminations. The results suggest that the behavior dissipation loops depend both on vertical load and horizontal shock.

## **Phase field fracture modeling of hydrogen embrittlement - Advances and opportunities**

*Kristensen, Philip K.; Niordson, Christian F.; Martínez-Pañeda, Emilio*

Hydrogen embrittlement has been a critical issue in the oil and gas industry for decades. Hydrogen from local corrosion processes can enter the lattice of structural steels and severely degrade the fracture properties of the metal, which may lead to unexpected fracture.

The Phase field fracture model is a promising new framework for modelling fracture, which has already found use in a great variety of fracture phenomena and multiphysics, making it a very promising candidate for effective hydrogen embrittlement modeling.

This poster details the authors' contributions towards advancing the phase field fracture model to technological maturity and identifying remaining concerns with the framework. In addition, examples of applications are provided to illustrate the potential of phase field fracture models for hydrogen embrittlement.

## REMOTE SENSING OF BREAKING OCEAN WAVES

### Utilizing LIDAR equipment for novel method of detecting breaking waves

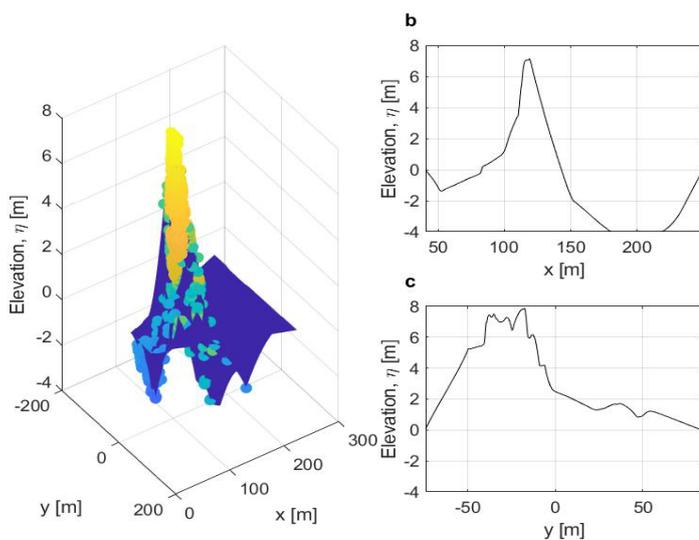
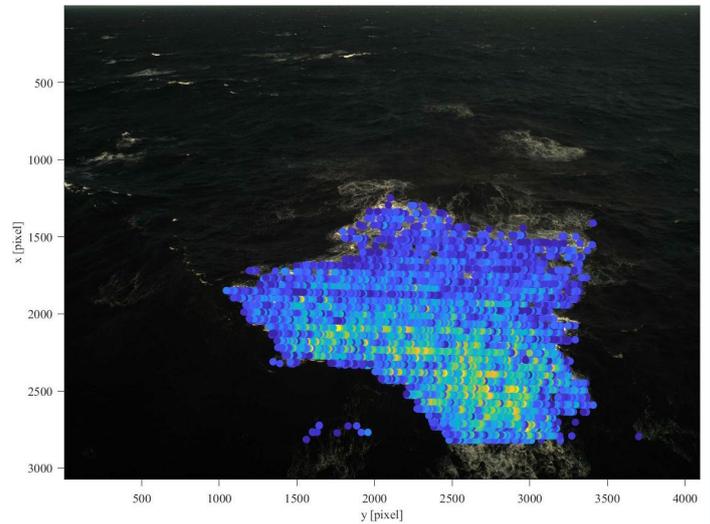
Thomas Kabel and Christos T. Georgakis

The poster shows the use of LIDAR equipment and how it can be used to detect breaking waves near offshore platforms in intermediate or deep level of waters.

Through the PhD project a focus has been on first, determining and verifying that actual waves are mapped using this LIDAR equipment. The second part, which is the primary focus of this poster, describes a new model that fuses the data of both the LIDAR and three different cameras. This enables us to detect at a specific point in a dataset, where we should focus our investigation and where the breaking of a wave occurs. Furthermore, this allows us to capture and follow the breaking event itself through time. Something that is novel and has yet to be seen before at full-scale.

Figure 1: Fusion of data, the point cloud on top of the visible camera

Figure 2: From left to right. Left: 3D point cloud of a breaking wave  
Mid: Cross-sections of the elevation of the breaking wave.  
Right: Visual confirmation of breaking event using visible camera



## **Structural damage detection using responses recorded during extreme events**

*Luigi Caglio, Evangelos Katsanos, Henrik Stang, Rune Brincker*

A considerable number of existing offshore platforms in the North Sea can be subjected during their lifetime to excessive wave loads, which may compromise their functionality and structural integrity. Especially, this issue can be of high relevance for structures that were built decades ago, and hence, have already undergone a slow deterioration of their materials and structural elements due to the aggressive marine environment and the external (wind and wave-induced) loads. Under these circumstances, a Structural Health Monitoring (SHM) campaign should be carried in order to reliably monitor and assess the structural integrity of those energy-related infrastructure systems even directly after an extreme event. An essential part of an SHM campaign is oftentimes a Damage Detection (DD) scheme, which aims to identify the structural damage that adversely affect the structural performance. Plenty of DD methods have been developed for onshore structures (e.g., buildings and bridges); however, their application to offshore platforms can be seriously challenged by several peculiarities related to the remoteness of those structures and the underwater installation of a considerable portion of the load-bearing structural system. In this context, the current study focuses on the localization and quantification of the structural damage that an offshore platform can experience due to extreme wave conditions. Apart from the design details (material, geometry of the structure and cross-sections), the only additional information available is considered herein to be structural responses recorded by sensors placed in few locations above the water level. The DD problem is approached herein as an input-state estimation problem for nonlinear systems. A Kalman Filter is used for the estimation of the input and the state while a nonlinear Finite Element model is used to account for the structural damage. The proposed DD scheme was tested on a 2D steel jacket structure subjected to various wave loads.

## **The effect of boundary conditions on the fatigue crack growth behavior of welded joints**

*Iman Shakeri, Martin Alexander Eder, Weijian Wu, Alexander Michel*

Most of the welded joints in offshore structures are subjected to fatigue loads, which lead to structural degradation and may eventually cause catastrophic failure. One way for increasing the fatigue life of the welded joints is to activate redundancies that lead to stress redistribution effects. This can be achieved by applying additional constraints to the local boundary conditions of the welded joints. As the effect of boundary conditions prevailing in the different welded joint designs are currently not considered in the present standards, codes and design recommendations, the design of such components can lead to over conservative solutions, which eventually leads to a significant increase in weight and cost. The aim of the present study is to investigate the effect of boundary conditions on the fatigue life of welded T-joints using 3D fatigue crack growth simulations. The numerical study shows that the crack growth behavior and consequently the fatigue life strongly depend on the applied boundary conditions – where particularly the axial membrane effect seems to play a significant role. The results of this investigation may lead to a more efficient design of welded joints in large scale structures.