DEPARTMENT OF CIVIL ENGINEERING
AALBORG UNIVERSITY

Scale 1:10 Test of the OWC WEC LEANCON at Nissum Bredning

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LEANCON
Wave Energy

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Aalborg University
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by

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1. Introduction

The LEANCON OWC WEC was deployed at the DanWEC test facility in Nissum Bredning at 23rd of July 2015 for test of real sea behaviour and provide experience in which areas, improvement and further investigation is needed. During the test period the device had to survive several storms, which resulted in failure of the primary mooring lines and smaller damage to the cables and steering box. These problems were fixed and allowed for further improvement. The number of test data is by now relatively limited, but gives indication on the devices capability to provide data and absorb energy. The main outcome of the project is therefore the experience and conclusions on where more investigation is needed. This conclusion, together with the problems that was solved during the project period, allows for a more detailed and thorough test series in future project.

Figure 1 - The LEANCON WEC at Nissum Bredning

1.1 The LEANCON WEC

The LEANCON WEC uses the oscillating water column (OWC) principle for harvesting of wave energy. The device advances by using both positive and negative pressure, thereby decreasing vertical forces on the structure. The structure consists of two “arms”, constructed into a V-shape, and with two rows of tubes (the OWCs) on each arm. The WEC is illustrated in Figure 2 and the working principle is illustrated in Figure 3. Due to the downwards suction force, arising from the negative pressure, the WEC is prevented from floating up on top of the waves, allowing the device to be made from light materials.

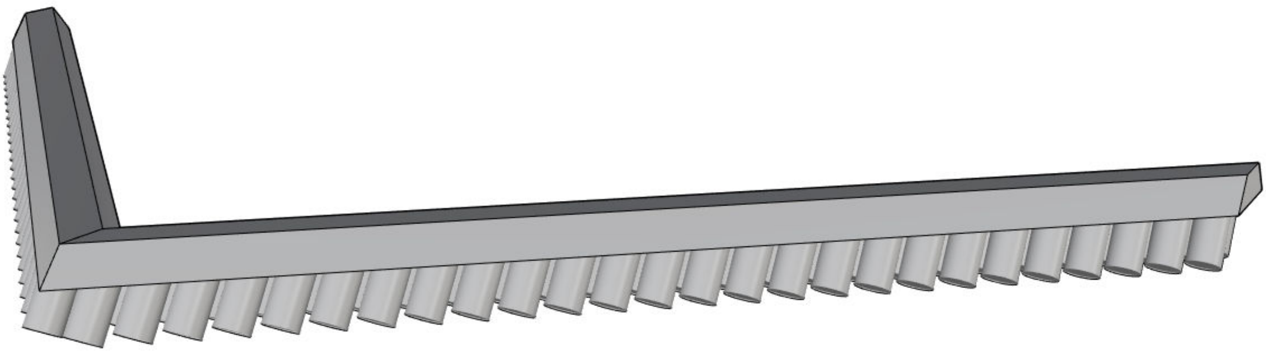

Figure 2 - 3D Model of the LEANCON device.

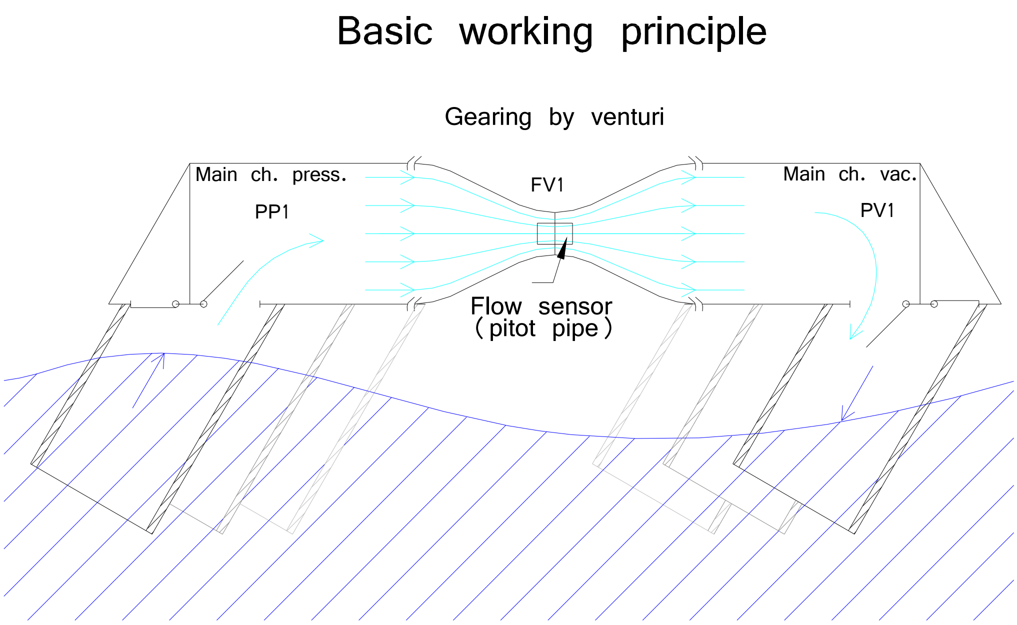

Figure 3 - Working principle of the WEC.

In severe storm conditions the devices is capable of closing the air valves, fill up the structure with air, and increase the buoyancy. The device will, in this situation, float on top of the waves and thereby decrease the induces wave loads.

1.2 Objectives

The objective of this test series has been to test the LEANCON device in real sea condition. The test is intended to highlight areas for further development, and identify which areas, that need further investigation in order to better evaluate the performance of the device. The test by now is meant to provide an indication on how the mechanics etc. is working and show if it is possible to put the device into the sea and harvest energy from the waves.

2. Test Set-up

The scale 1:10 model deployed at Nissum Bredning is constructed of two identical arms, and the energy production is measured in the right arm. In order to estimate the energy, the pressure and flow are measured. Two measure units are located at the right arm (cf. Figure 4 for position) and can be seen in Figure 5.

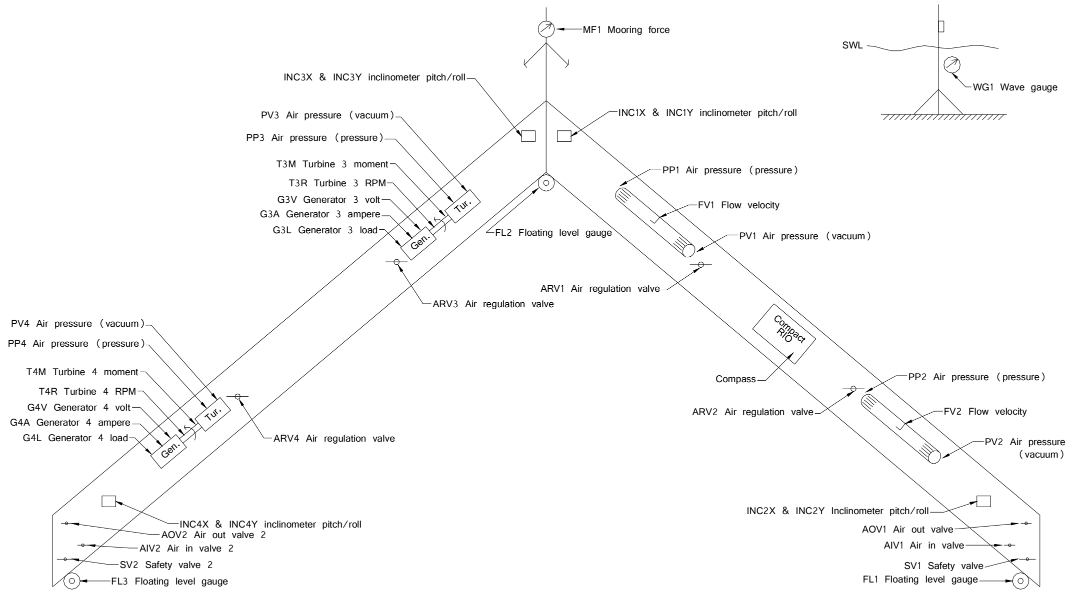

Figure 4 - Test set-up.

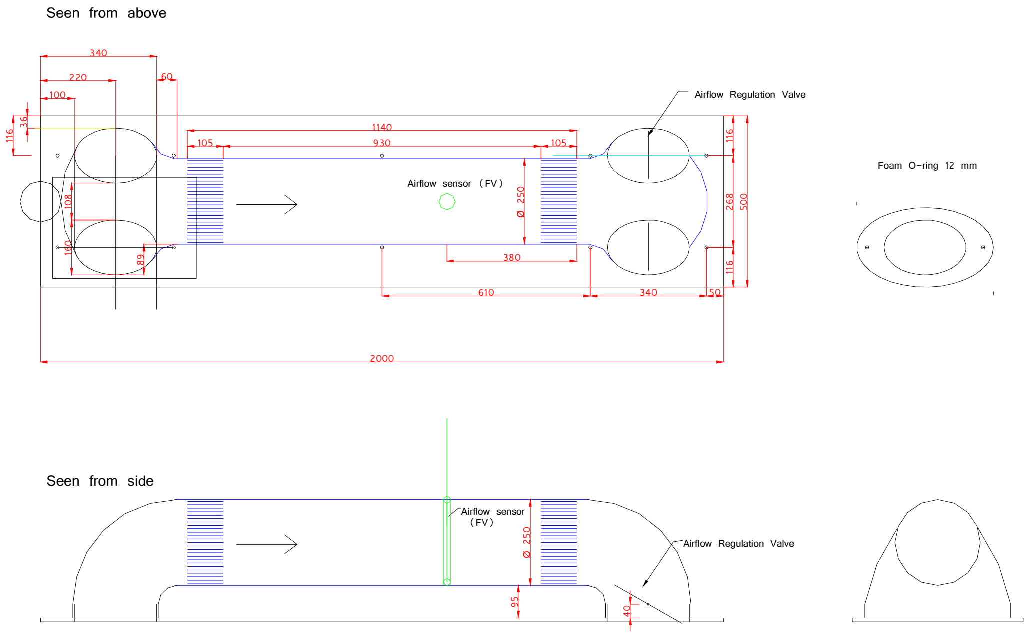

Figure 5 - Air flow units.

The air flow unit illustrated in Figure 5 corresponds to the flow unit illustrated in Figure 3. The unit consists of a pressure channel, with a pressure PP1 and vacuum channel with the pressure PV1. The flow from the pressure channel to the vacuum channel is defined as FV1. A similar configuration is present in the second flow unit. The energy production is defined by the pressure difference between PP1 and PV1 multiplied with the flow FV1. The total flow is the sum of the energy calculated from the two flow units.

The flow velocity is defined by measuring the pressure difference between the two channels, and calculated into a velocity based on tables produces by the manufacturer of the pressure equipment. The flow velocity is converted into a flow, based on the cross-sectional area A of the flow pipe.

The total energy production P_{tot} in the right arm is defines as:

$$P_{tot} = (PP1 + PV1) \cdot FV1 \cdot A + (PP2 + PV2) \cdot FV2 \cdot A$$

As seen from Figure 4, a mooring system is connecting the device to the seabed. The layout of this system is illustrated in Figure.

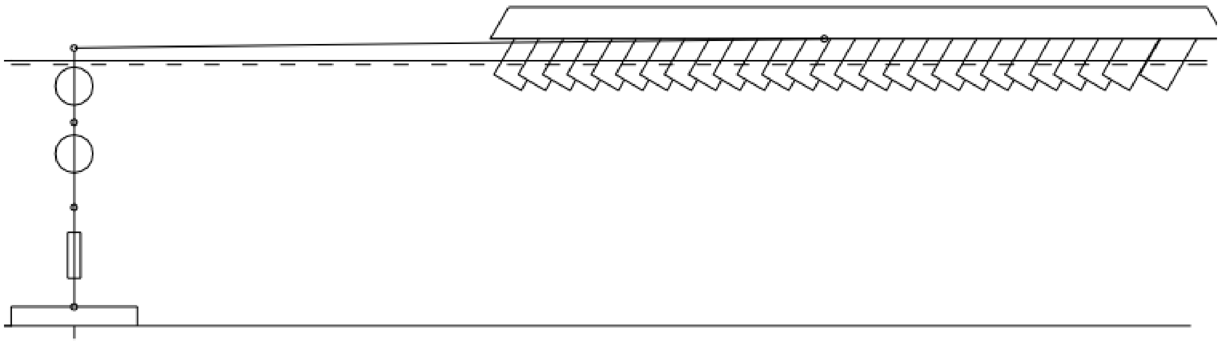

Figure 6 - Side-view of mooring system.

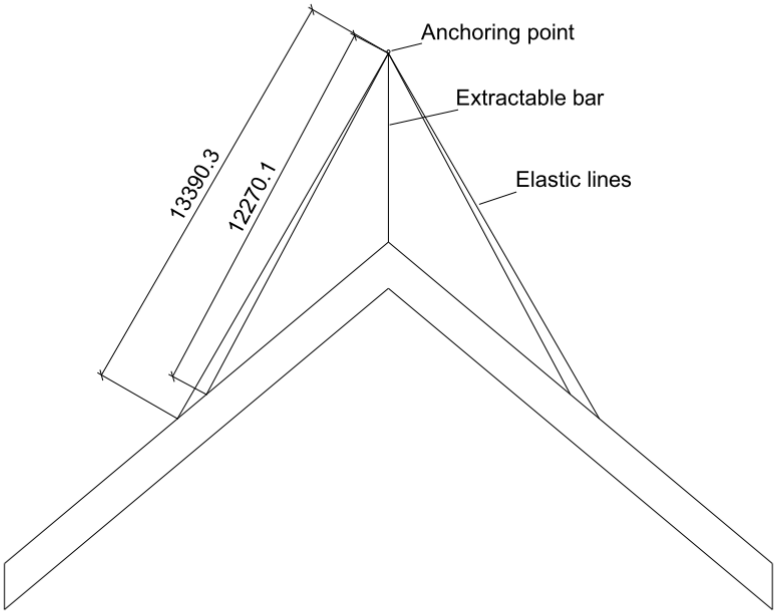

Figure 7 - Top-view of mooring system.

The system consists of two submerged buoys, three steel rods, universal joints and four nylon lines. The nylon lines are chosen to be as thin and elastic as possible, in order to ensure a much compliant system. The anchor is of the gravity type, and consists of a concrete block. A safety system is applied and is made up of strong lines, that only works in case of failure of the four nylon lines. One load cell was applied to the mooring system allowing for measurements of the total horizontal mooring force.

A wave gauge was installed for determination of the sea state.

3. Test Data

As mentioned, the total number of data was limited and future investigation will be beneficial. A few test series with different configurations will be used to illustrate the potential of the device and illustrate that the device is capable of producing energy and that the equipment is capable of measure the quantity.

Four representative test samples were selected for this report, all measured the 1st October 2015, hence in similar environmental conditions.

3.1 Power Production

The following plots tends to illustrate the influence of different configurations of the device, and that systems capability to harvest energy. Figure 8 illustrates the measured air pressure in the pressure and vacuum chamber during a time sample. Note that the vacuum is also measured as a positive value. In addition, Figure 8 presents the measured airflow velocity during the same time sample.

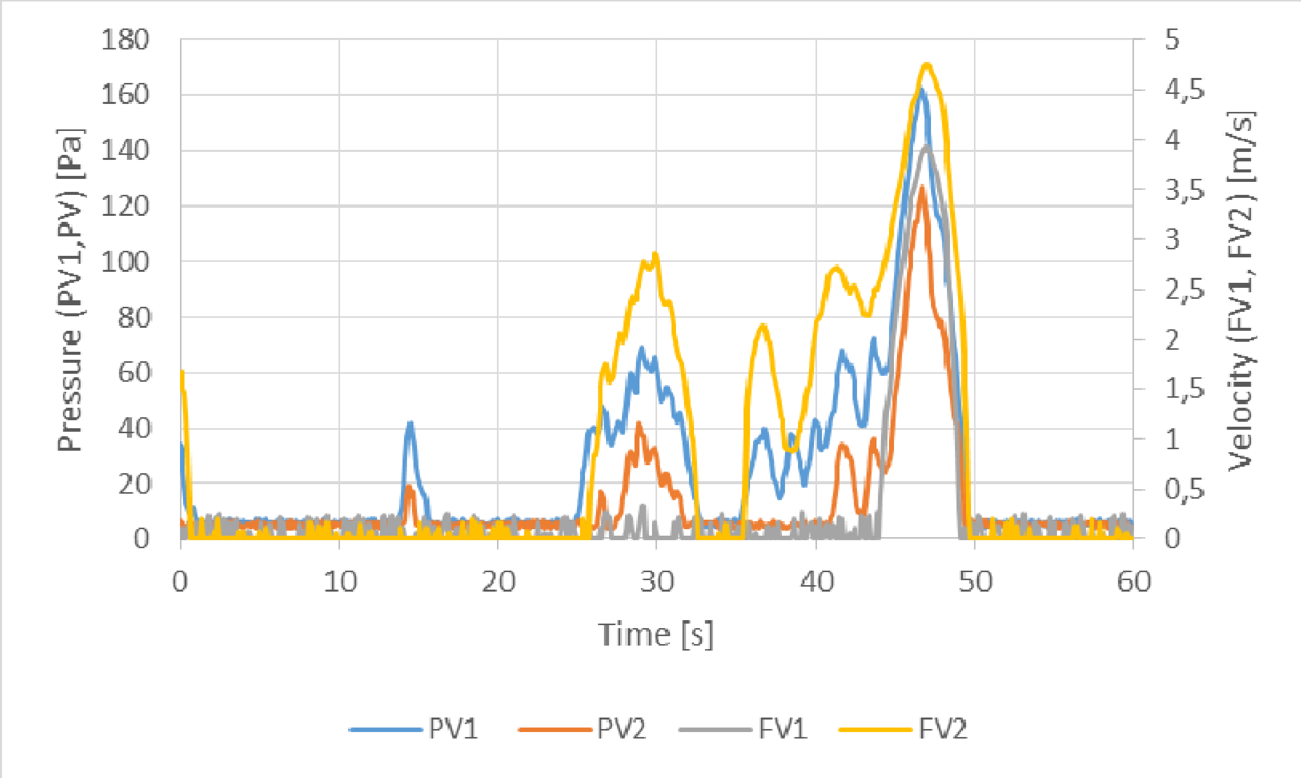

Figure 8 - Pressure and airflow velocity measured during sample.

The airflow in the device can be controlled by adjusting an air valve. Figure 9 illustrate the difference in measured power production, when the air valve is open respectively 30°, 19° and 7°. In addition to the air valve, a safety valve is also installed. In operational condition, this is opened 90°, while being closed when the WEC is in safety mode. A time series in safety mode is also plotted in Figure 8.

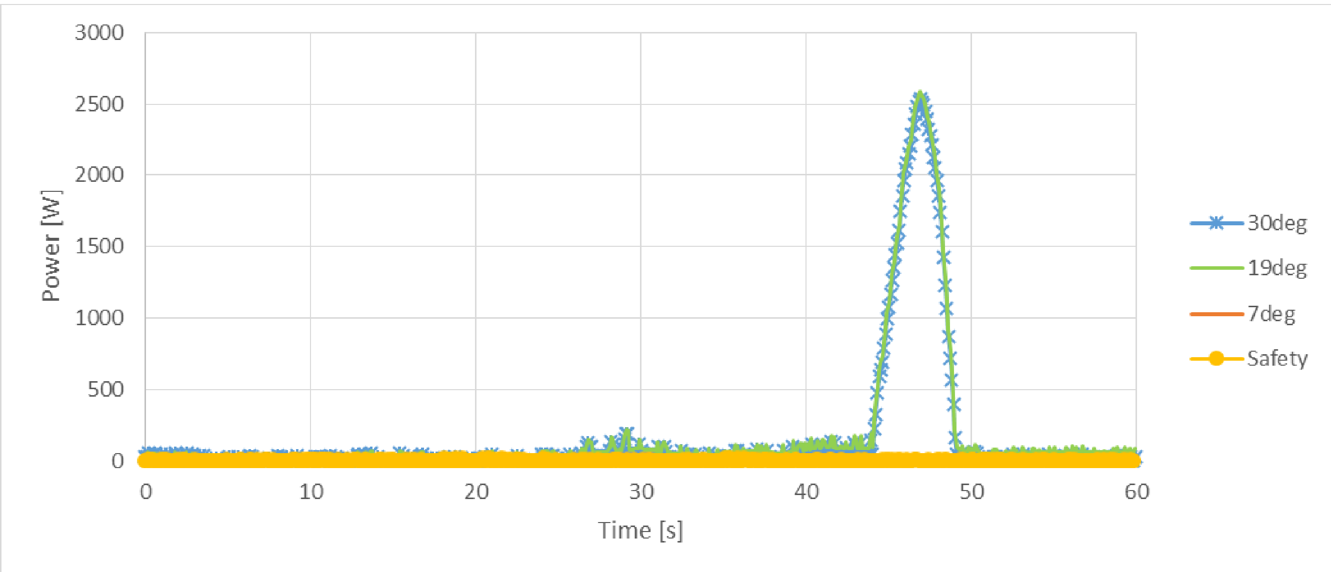

Figure 9 - Measured power with differenct air valve configuration.

From Figure 8 it is seen, that when having a air valve in 30° most energy is extracted, while 10° provides slightly less. When the air valve is 7° open, very little energy is extracted, and in safety mode no energy is harvested. The given time series are very short, and further investigation is needed to make full conclusions on energy production. Installing additional equipment for measuring the flow and pressure would also provide more information on the energy production, and allow for more information and a better basis for optimization.

3.3 Mooring Results

The mooring load was measured in the same time series as listed above. Figure 10 presents the mooring load measured in safety mode and when the air valve is 30° open. For the short time series, it is difficult to conclude anything on the size of the mooring loads. Figure 10, to some extent, indicates that the average mooring load is slightly lower in safety mode than when the air valve is opened.

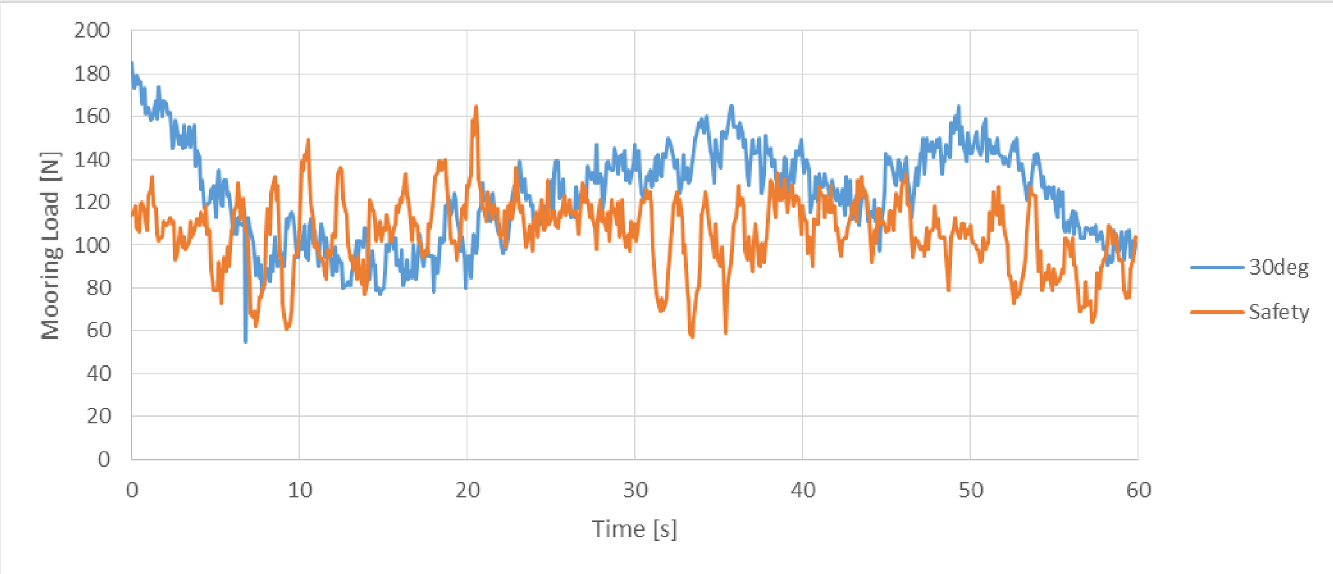

Figure 10 - Mooring load measured in 30deg configuration and in safety mode.

In addition to load cells and air flow units, different inclinometers (cf. Figure 4) was installed. Figure 10 plots the mooring load together with one of the inclinometers. A correspondence between the motion and mooring loads is present, verifying the measurements. In order to better understand the correlation between motion and mooring loads, it would be beneficial to have better description of the motions. This could e.g. be achieved by installing accelerometers allowing to get indications on motions in all directions. Similarly, load cells in all mooring line, and not just one in the resultant direction would give a better indication on how the loads are distributed in the lines, and how the mooring could be optimized.

As mentioned earlier the mooring line broke, during the storms that occurred in the test series. In order to get a system that is highly compliant, very thin lines had been chosen, and in addition, the system was designed so that at a given mooring load, the safety lines would provide strength to the system. This required some calibration and might have caused the failure of the lines, as it appears that the safety line did not take action until after the primary lines were broken. More investigation is highly needed in this area.

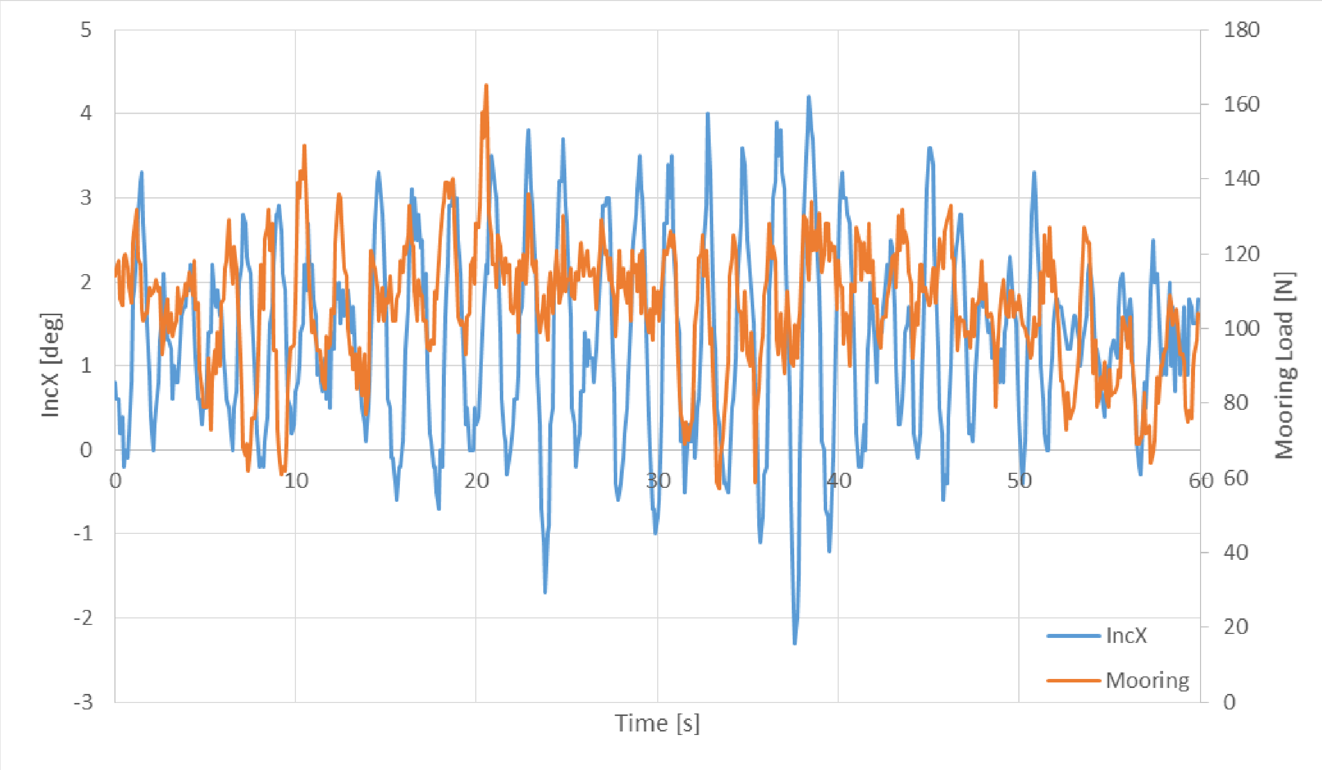

Figure 11 - Mooring load and inclinometer measurements.

6. Conclusions and Future Work

The LEANCON WEC has proven to be able to survive more than 4 month in sea at the Nissum Bredning tests site. An indication on mooring loads, energy production and motions has highlighted in which areas more information is needed. The device was able to survive several storms and was shown capable of providing tests results for a range of parameters. The mooring broke twice during the test period, but the back-up system proved to be strong enough to secure the device. The cause of this failure was investigated, and action towards solving it, has been initiated. In order to better understand the behaviour of the mooring and the induced load, an improvement of the system, could be to install load cells in all four mooring lines. Motion tracking equipment in terms of e.g. accelerometers, could similarly provide useful information about the system behaviour in future tests.

Few indications on the energy production was provided by time series with different air valve configurations. The device proved to be able to extract energy in operational mode, while also initiate a safety mode, with no energy extraction and where smaller mooring load seems to be induced. Installing additional equipment in the air flow unit could allow for further investigation of the air flow and possible optimizations, which is vital and easier in smaller scale devices, and should be done before larger scale devices are build.

In order to get a full and better description of the system behaviour in real sea, additional tests are necessary. This first test series has allowed for installing the device and improve several problem areas that expectedly occurred when the device was putted in the sea. The experience from this first test series, should be used in future tests and allow for a full and more thorough investigation. An initial step toward future offshore sea tests, could be to test one arm in a large wave basin with more controlled environment, allowing for more detailed and thorough investigation.

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