LiftWEC

DEVELOPMENT OF A NEW CLASS OF WAVE ENERGY CONVERTER BASED ON HYDRODYNAMIC LIFT FORCES

Deliverable D4.4

Report on physical modelling of 2D LiftWEC concepts

Deliverable Lead	Ecole Centrale Nantes
Delivery Date	17/11/2021
Dissemination Level	Public

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Document Information

Project Acronym	LiftWEC
Project Title	DEVELOPMENT OF A NEW CLASS OF WAVE ENERGY CONVERTER BASED ON HYDRODYNAMIC LIFT FORCES
Grant Agreement Number	851885
Work Package	WP04
Related Task(s)	T4.2
Deliverable Number	D4.2
Deliverable Name	Report on physical modelling of 2D LiftWEC concepts
Due Date	30th May 2021
Date Delivered	17th November 2021
Primary Author(s)	Florent Thiebaut (ECN)
Co-Author(s)	Grégory Payne (ECN)
Document Number	LW-D04-04

Version Control

Revision	Date	Description	Prepared By	Checked By
0.1	25/10/2021	Draft for internal review	Florent Thiebaut	Gregory Payne
1.0	17/11/2021	Release for publication	Florent Thiebaut	Matt Folley Remy Pascal Julia Chozas

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

EXECUTIVE SUMMARY

The experimental test campaign of a two-dimensional model of the LiftWEC concept, with one or two foils, was carried out in June and July 2021. The 2D model was designed, built, assembled and commissioned by Ecole Centrale de Nantes (ECN). The model allows testing of configurations with one or two foils, with adjustments before each test of the foil angle of attack and of the rotor diameter. The model was tested in the ECN wave and towing tank, in a narrow "sub-channel" made of partition walls, which reduced the flume width locally. The idea behind this approach was to use a tank capable of generating large waves while keeping the width of the device and hence loads on the device more manageable, thus reducing complexity and costs. The sub-channel was composed of two parallel walls at 0.49m distance and the foils have a constant shape across the channel so that the water motions are in two dimensions. The motion of the rotor was controlled using a power take-off (PTO) system consisting of an electrical machine which can be operated in fixed position, speed or torque control. The quantities measured are the PTO torque, radial and tangential loads on the axis of each foil, absolute angular position of the rotor and wave elevation upstream and downstream of the model. From those measured quantities, rotor velocity and acceleration as well as captured power can be inferred.

The present document describes in detail the test campaign carried out in June and July 2021. It gives details on the model setup, testing carried out, data processing and validation. The data and the full test matrix were published in Zenodo under DOI: https://doi.org/10.5281/zenodo.5596066 and are now free to access. This dataset replaces the initial dataset, published under DOI: https://doi.org/10.5281/zenodo.5534471, which does not include processed data described in this document.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

TABLE OF CONTENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

1 INTRODUCTION

This document describes the experimental testing of the LiftWEC 2D model in the wave and towing tank at Ecole Centrale de Nantes (ECN) in June and July 2021. This document provides detailed information on the experimental setup, wave testing carried out and the data acquisition and validation.

The open access dataset is available from the online repository Zenodo, with DOI: https://doi.org/10.5281/zenodo.5596066. This dataset replaces the initial dataset, published under DOI: https://doi.org/10.5281/zenodo.5534471, which does not include processed data described in this document.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

2 Experimental Setup

2.1 Wave basin

The wave and towing tank at Ecole Centrale Nantes (ECN) offers a 5-meter wide, 140-meter long and 3-meter deep testing volume.

Figure 2-1: ECN wave and towing tank

The tank is equipped with a wavemaker composed of a single hinged flap covering the entire width of the tank. The wavemaker control software, used together with enhanced control laws from the literature can generate either idealised theoretical waves (e.g. monochromatic waves, wave packets) or complex representative unidirectional sea states. The wavemaker can generate waves up to 0.46 meter in height at specific periods, as shown by its operational diagram in Figure 2-2. At the other end of the basin, a seven meters long passive stainless steel beach with quadratic profile, shown in Figure 2-3, dissipates most of the wave energy through breaking processes. Additional floating lines were used to improve the dissipation of high frequency waves.

The tank is equipped with a towing bridge, which was not in use for this project.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

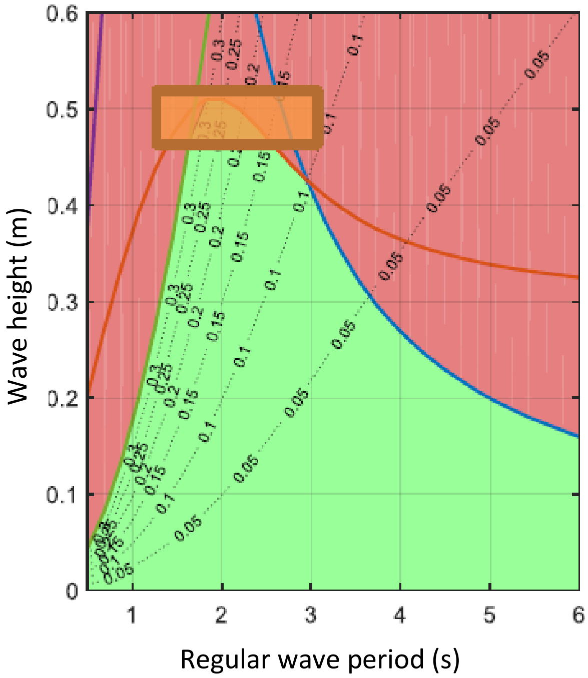


Figure 2-2: Performances of ECN's towing tank wavemaker (green area)

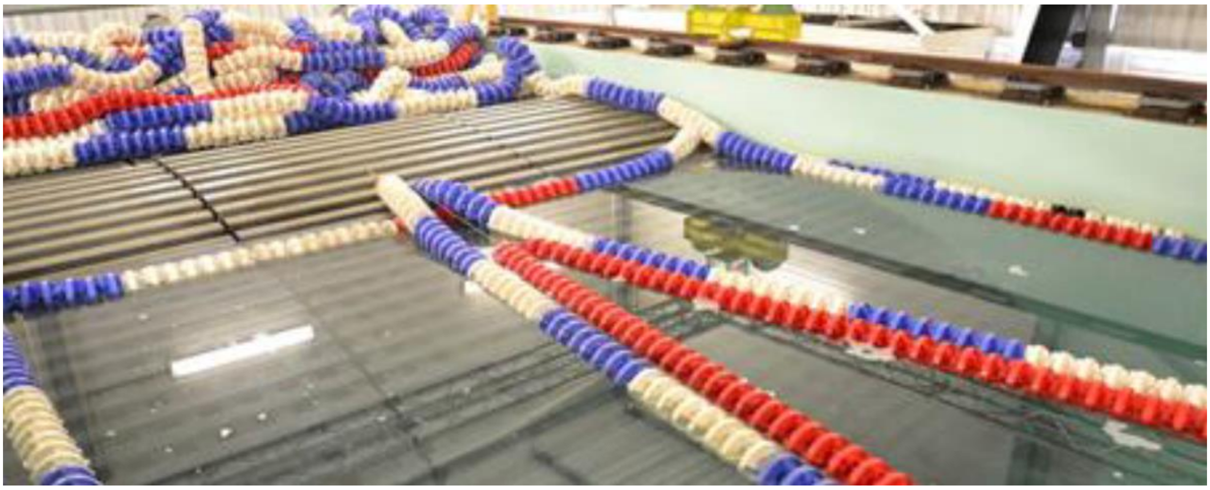


Figure 2-3: Tank beach and swim lines for wave absorption

Water in the tank is fresh water that remains permanently and has a density of 999 grams per litre.

The gravitational acceleration g is equal to 9.80824 at Nantes (value from https://www.sensorsone.com/local-gravity-calculator).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

2.2 MODEL DESIGN AND SETUP

LiftWEC deliverable LW-D04-01 gives details of the model in the design phase. This section includes the main model parameters that are required to describe the hydrodynamic characteristics and the data acquired.

The model is composed of two vertical walls creating a sub-channel with flat surfaces. This creates a narrow flume where the waves can propagate in 2D motion. The rotor hydrofoils and its shaft are the only elements inside the sub-channel and their geometries are constant across the sub-channels, allowing 2D motion of the water particles around the hydrofoils. All other parts of the model are outside of the channel so that they do not interact with the water motion. Table 2-1 gives the main geometry of the model, sub-channel and wave flume.

The foil pitch is defined as zero when the foil cord is parallel to the direction of motion. It is positive when the leading edge is further away from the rotor axis of rotation. This is illustrated in Figure 2-9.

The model is made of the following elements:

- The central section of the sub-channel, shown in Figure 2-4, placed at the centre of the tank so that the model is 50m from the wavemaker.
- Vertical walls completing the central section of the sub-channel on both side parallel to the wave propagation direction. Therefore, the rotor axis is at the middle of the 17.3m sub-channel.
- All other elements of the model are on the assembly shown in Figure 2-4 and Figure 2-5, and are composed of the electrical motor, the rotor and support structure including vertical walls completing the shape of the sub-channel above the central section. It is placed on the central section during testing and can be easily removed with the overhead crane to change model configuration.

Figure 2-6 shows a close-up of one of the foils of the model. Figure 2-7 shows the rotor in action within the subchannel during testing. In the middle and at the top of the picture, the underwater camera can also be seen.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Description	Unit	Dimension
Tank length	m	140
Tank width	m	5
Tank depth	m	3
Sub-channel width	m	0.49
Sub-channel length	m	17.3
Sub-channel height	m	3.3
Rotor diameters	m	0.5, 0.6 or 0.75
Pitch angles	degrees	[-12, -8, -4, 0, 4, 8, 12]
Hydrofoil profile		Curved NACA0015/NACA3515
Depth of rotor axis	m	0.755
Hydrofoil chord length	m	0.3
Hydrofoil chord curve radius	m	0.3
Number of hydrofoils		1 or 2

Table 2-1: ECN 2D experimental setup main geometry

Figure 2-4: Overview of the model structural elements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

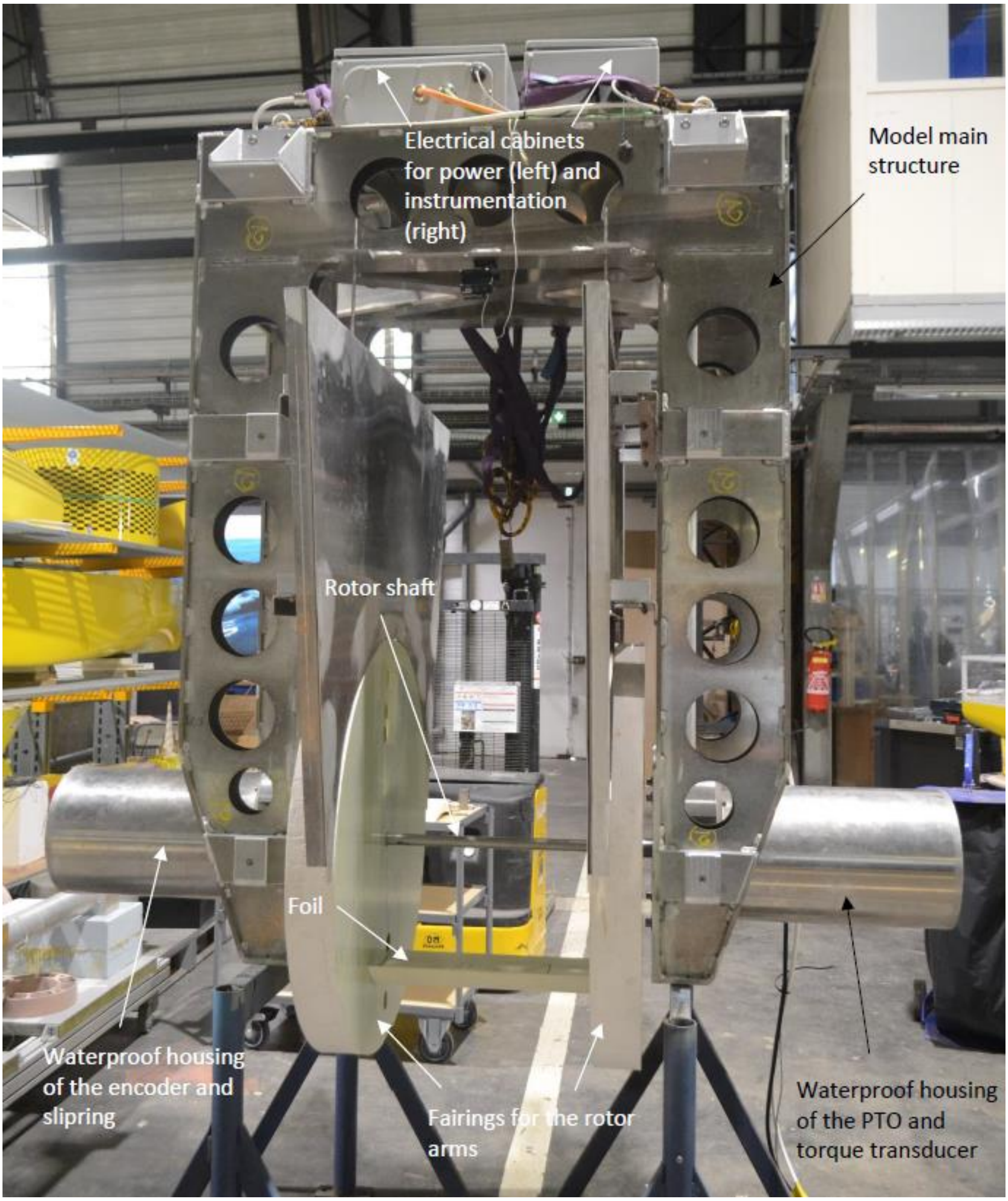


Figure 2-5: Overview of the rotor and support structure

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

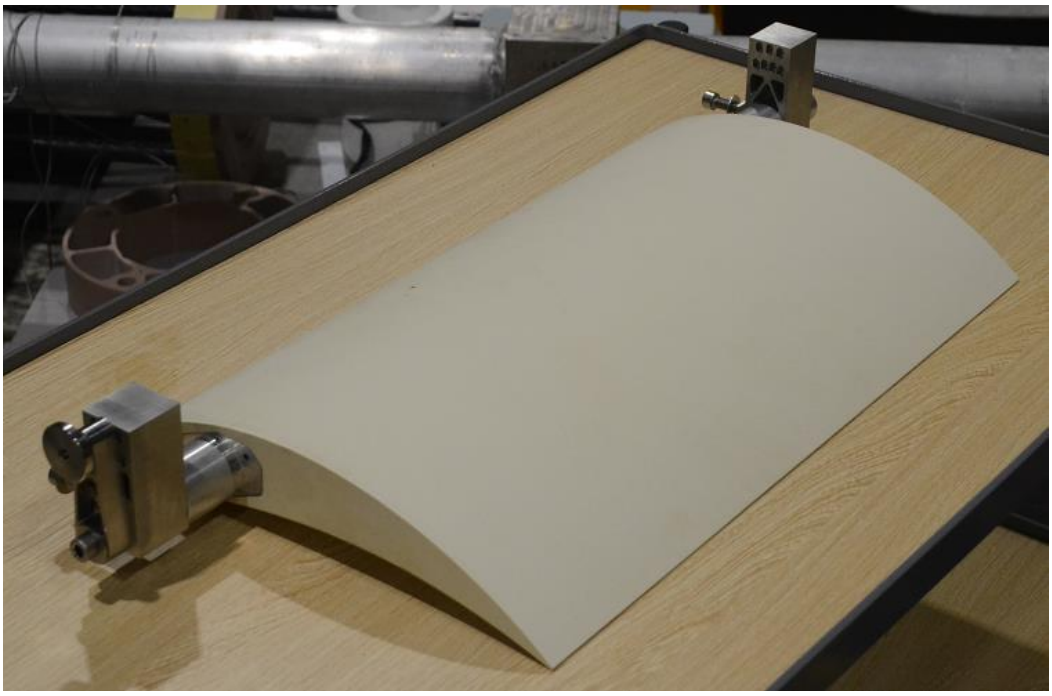


Figure 2-6: Picture of one hydrofoil used in experimental testing

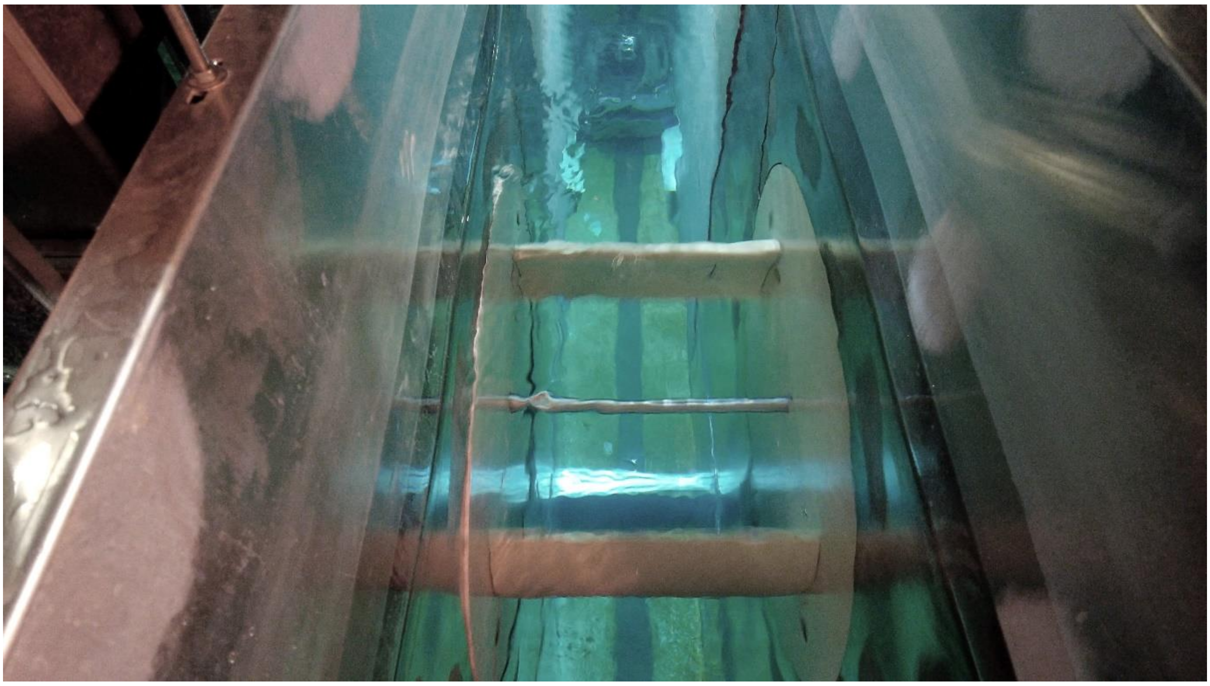


Figure 2-7: Rotor and underwater camera (top of the picture) during experiments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

2.3 INSTRUMENTATION

2.3.1 Wave gauges

Eleven wave gauges, measuring water surface elevation, were deployed in the tank within the sub-channel for wave calibration, without the model installed on the central section. The list of wave gauges and locations are in Table 2-2 and illustrated in Figure 2-8. This setup allows measurement of the reflected waves in front and behind the model with four wave gauges aligned at the centre of the sub-channel either side of the model. In addition, two wave gauges placed either side of WG4 in the direction perpendicular to the wave propagation direction gives an estimate of the lateral waves across the width of the sub-channel.

During testing with the active part of the model (rotor, foils, etc.), wave gauge 5 was removed to leave space for the rotation of the foils.

Wave gauge ID	Wave gauge length (m)	Position X (m) (distance to paddles)	Position Y (m) (Relative to basin centreline)	Comments
1	0.6	47.8	0	
2	0.6	47.95	0	
3	0.6	48.3	0	
4	0.6	49	0	
5	0.6	50	0	Wave calibration only
6	0.6	51	0	
7	0.6	51.15	0	
8	0.6	51.5	0	
9	0.6	52.2	0	
10	0.6	49	0.12	
11	0.6	49	-0.12	

Table 2-2: Position of wave gauges in the basin (model scale)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

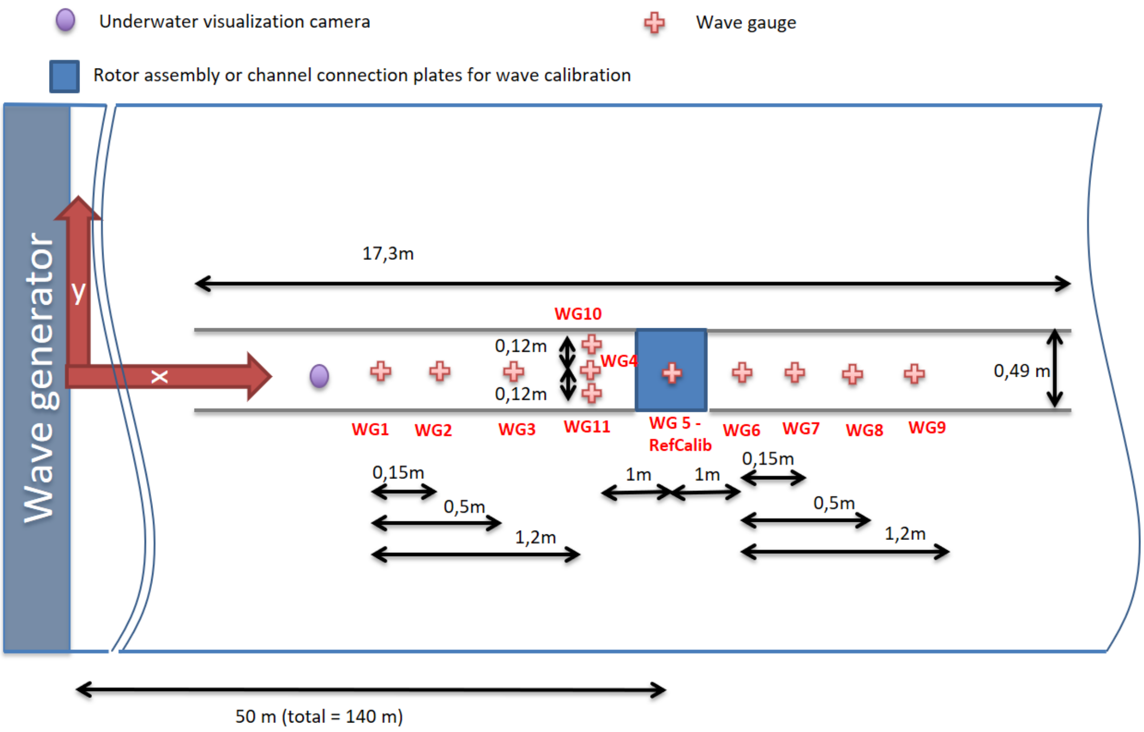


Figure 2-8 : Illustration of wave gauges position in the flume and sub-channel.

All wave gauges were calibrated before installation in the basin, with the same cables and acquisition system as used during tank testing. The calibration rig is outside the basin and composed of a controlled linear actuator and a tank filled with water pumped from the basin to ensure same water conductivity. Calibration results for all wave gauges are in appendix A.

2.3.2 Load cells

Eight load cells measured the load applied from the two foils on the rotor arms. Two are located on either side of each foil and measure the load in radial and tangential directions. The radial direction is parallel to the line passing through the centre of the rotor and the centre of the foil (half of the cord length). The tangential direction is perpendicular to the radial direction. The list of load cells and their measured parameter is in Table 2-3.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Sensor	Direction	Side	Foil
F1	Radial	Motor	1
F2	Tangential	Motor	1
F3	Radial	Motor	2
F4	Tangential	Motor	2
F5	Radial	Collector	1
F6	Tangential	Collector	1
F7	Radial	Collector	2
F8	Tangential	Collector	2

Table 2-3: List of load cells and measured parameter

The description of measured radial and tangential forces is shown in Figure 2-9. The loads are measured at a distance of a quarter of the foil cord length from the leading edge and the direction of the radial force is parallel to a line passing through the axis of rotation and the centre of the foil (half foil cord). The radial force is positive when the force applied by the foil on the rotor is directed away from the centre of rotation. The tangential force is positive when the force applied by the foil on the rotor is directed towards the leading edge, in this direction the foil is accelerating the rotor or generating power.

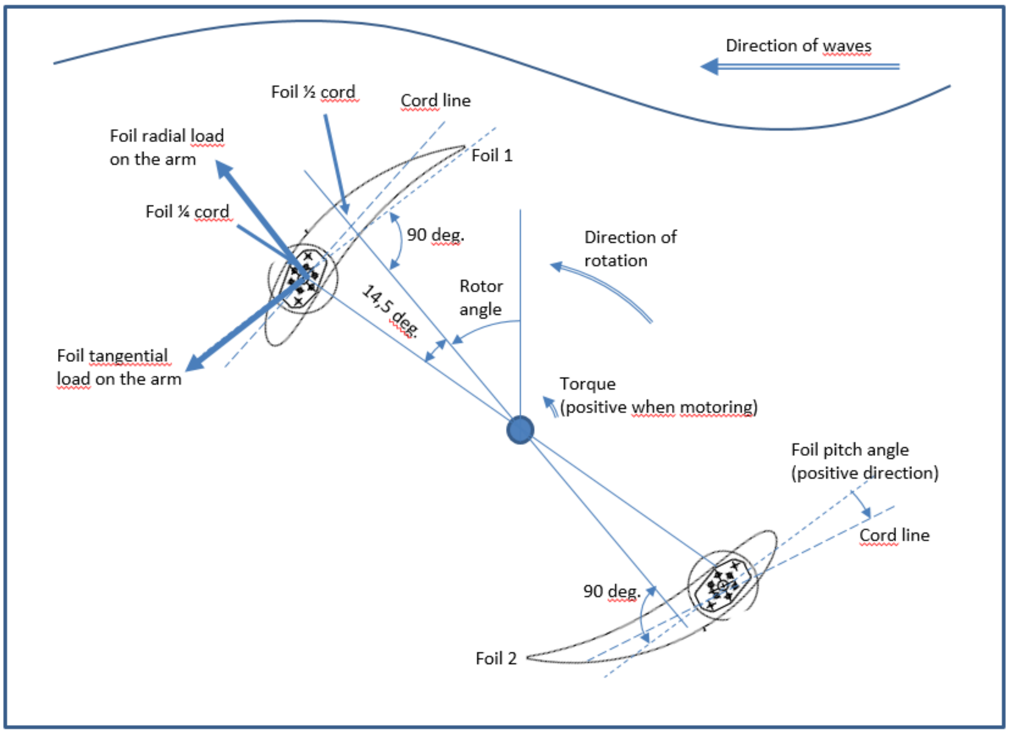


Figure 2-9: Illustration of radial and tangential force measured by the load cells

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

The load cells selected are manufactured by the German company HBK, see picture in Figure 2-10. The models details are:

- K-Z6-F-C3-0030-N-S3-N (300N capacity) for the radial direction
- K-Z6-F-C3-0010-N-S3-N (100N capacity) for the tangential direction

Figure 2-10: Picture of a load cells use during the experiments

All load cells were checked before installation on the model and were calibrated once on the model with final cabling structure, through the arms and slip ring. The calibration results are in appendix B

2.3.3 PTO torque transducer

A torque transducer with a torque rating of 100Nm, measures the torque on the motor shaft. It is produced by the German company ETH-messtechnik and the model is DRBK II 100 A. The sensor is located in the motor dry enclosure and in series between the motor shaft and the main rotor shaft, arms, foils, etc.

The torque transducer could not be calibrated at ECN and the measurements are based on the sensor datasheet and the factory certificate in Appendix C.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Figure 2-11: Picture of the torque transducer used during the experiments

2.3.4 Angular position

A magnetic encoder measures the rotor angular position, it is placed in the dry enclosure on the slip ring side of the model. The moving part is attached to the shaft in line with the motor and torque meter and it has a resolution of 4096 pulses per turn, corresponding to an angular resolution of 0.09 degree. The encoder is produced by the German company Automation Sensorik Messtechnik (ASM). The magnetic disk model is PMIR5-50-64-M-83-AB and that of the reader head is PMIS4-50-64-20KHZ-TTL-Z3-3M-S

The encoder has a reference position, which is used to calibrate the absolute position measurement. When the encoder is turned on, the absolute position is not known but when the reference position is sensed (after one turn maximum) the acquisition system corrects the measured value to the known position of the reference. This action was done before testing, each time the acquisition system was restarted, and therefore does not affect the acquired files, which always give the absolute position.

The angle value is zero when the line passing through the centre of the rotor and the centre of the foil (half of the cord length) is vertical and the foil 1 is at its highest position. The recorded value is wrapped between 0 and 360 degrees.

2.4 Control and Acquisition System

The control and acquisition system, illustrated in Figure 2-12, is composed of

- A CompactRio, CRio 9045, for the motor control and for motor torque measurement. It records at 500Hz.
- Two HBM Quantum MX1601B signal-conditioning unit for all other sensors. It records at 150Hz.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Both acquisition systems are operating independently and are connected to two computers. The two systems were starting prior to the wavemaker and record a synchronisation signal with a rising edge corresponding to the start time of the wavemaker.

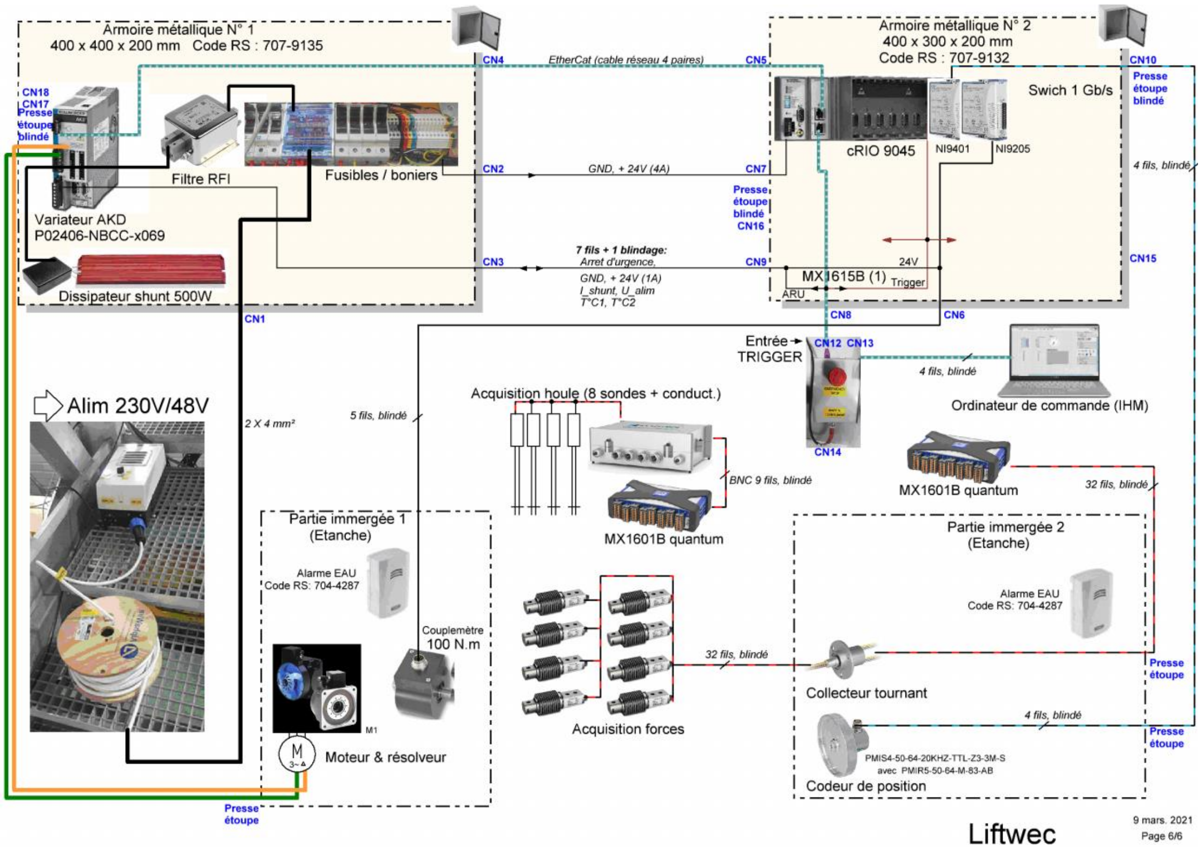


Figure 2-12: Illustration of the motor control and data acquisition system

2.5 VIDEO CAMERAS

An underwater video camera placed at the bottom of the flume (on the incoming wave side) in the sub-channel captured a video for each test. It is a PTZ CCTV camera with HD resolution and an optical zoom of x25. The camera and its waterproof housing are shown in Figure 2-13.

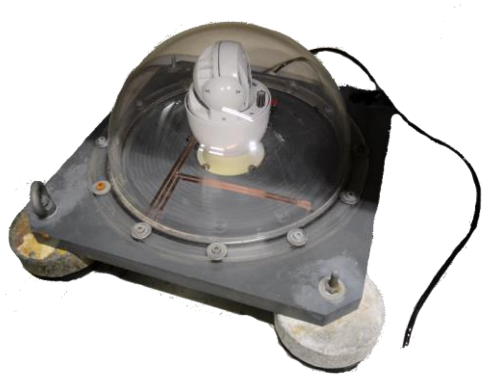


Figure 2-13: Underwater video camera used in the experiments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

3 EXPERIMENTAL TESTING

3.1 TEST METHODOLOGY

During the test campaign more than 200 tests were carried out. The specific wave conditions and model configuration was set for each test as per the test requirements and was logged in the test matrix.

The wave calibration method, applied to each test, follows the steps below:

- Setup of the data acquisition system for the next test.
- Selection of the next wave case to generate, following the test requirements.
- Start wave generation when waves in the basin are visually settled and the wave heights measured on the wave gauges are below about 2% of the height or significant wave height of the next wave case.
- Check the data recording started with the trigger and all sensors show reasonable values.
- The test duration is set and the wavemaker stops automatically
- Stop the acquisition system manually after the wave generation system has stopped.
- Verify the raw data file is saved correctly in the acquisition computer

The model testing method, applied to each test, follows the steps below:

- Setup of the data acquisition system for the next test.
- Setup of the motor control and acquisition system for the next test.
    - When the foil to wave phase angle needs to be set, the position control mode is used to place the foil at the required initial position and the control is then switched to constant speed mode with a calculated time delay from the wavemaker trigger to start the rotation.
- Selection of the next wave case to generate, following the test requirements.
- Start the video camera
- Start the master controller when waves in the basin are visually settled and the wave heights measured on the wave gauges are below about 2% of the height or significant wave height of the next wave case. This automatically:
    - Starts both acquisition systems with a first trigger high level
    - Starts the wavemaker after a set time to measure the zero value for each sensor. The wavemaker sends an electrical trigger recorded in both acquisition files and shines a red light visible on the underwater video camera for manual synchronisation if required after testing.
    - Stops the wavemaker after a set time
    - Stops both acquisition systems with the first trigger back to low level
- Check the data recording started with the trigger and all sensors show reasonable values.
- After the test stops, verify the data files and video file are saved correctly in the acquisition computers

Each test has a unique test number recorded in the test matrix together with relevant test conditions and comments.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

3.2 TEST MATRIX

The test matrix in this section provides the final information on the list of tests carried out during the test campaign. It includes the wave characteristics, model configuration and PTO control strategy. The test matrix is presented in Table 3-1 to Table 3-6 and gives all parameters required for data analysis. Represented columns are:

- Test num: The unique test number, which is used in all the project reports, data files, etc.
- Date: Date of the test
- Wave type: type of wave generated during the test, it may be:
    - DRY: model test outside the tank
    - ZERO: no wave generated
    - RW = Regular waves
    - BiW = Bi-chromatic waves
    - IW = Irregular waves (Jonswap spectrum)
- T/Tp(s): wave period (regular) or Peak period (irregular)
- H/Hs(m): wave height (regular) or Significant wave height (irregular)
- T2_s: second wave period in bi-chromatic waves only
- H2_m: second wave height in bi-chromatic waves only
- Gamma: Spreading factor for Jonswap wave spectrum
- Foil phase: Requested phase angle between wave peak and foil 1 position (or foil 2 when only foil 2 is in use)
- Vrotor_Rad_sec: Rotor speed in motor constant speed mode
- Added vel. Amp(deg/s): Rotor added velocity amplitude, motor control with velocity time series
- Added vel. period (s) : period of the rotor added velocity amplitude
- Pitch1: Foil 1 angle, NA means this foil is not on the model
- Pitch2: Foil 2 angle, NA means this foil is not on the model
- Comments: Any comment or observation during the test

In addition, some parameters were used in ECN during testing and for ECN data processing described in section 4. Theses parameters are shown in the test matrix used during experimental testing, which is in the excel file “LW-WP04-FT02-1x1_2D_TestMatrix.xlsx” published in Zenodo with the data files under DOI: https://doi.org/10.5281/zenodo.5596066. The parameters not shows in Table 3-1 to Table 3-6 are:

- Duration: minimum duration requested for analysis
- Test type: same as wave type but adding “Calib” for wave calibration
- WCalibTestNum: Number of the wave calibration test in which the wave characteristics are the same as the present test
- ZeroCalib_num: Number of the ZERO test at 0.1 radian per second, giving the load zero reference curve.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

- Rot.pos_T0: position of the rotor to be set before starting the waves to achieve required foil phase angle.
- Tdelay_s: time delay to start the rotor in constant velocity mode to achieve required foil phase angle.
- Vrotor(s/rotation): Rotor velocity given in seconds per full rotation.
- Foils on model: list the foils installed on the model
- Radius: Distance between rotor axis of rotation and foil cord. It remains 0.3m for the entire test campaign.
- ChannelList: Information only relevant for the ECN analysis software
- Done: Information only relevant for the ECN analysis software

Note: all test are with 0.3m radius of rotation of the foil quarter cord point.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Test num	Date	Wave type	T/Tp(s)	H/Hs(m)	T2_s	H2_m	Gamma	Foil1 phase	Torque Max	Vrotor_Rad_sec	Added vel. Amp(deg/s)	Added vel. period (s)	Pitch1	Pitch2	Comments
2	30/06/2021	RW	1.00	0.048	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
3	30/06/2021	RW	1.42	0.090	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
4	30/06/2021	RW	1.21	0.070	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
5	30/06/2021	RW	1.00	0.080	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
6	30/06/2021	RW	1.83	0.150	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
7	30/06/2021	RW	1.60	0.120	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
8	30/06/2021	RW	1.42	0.153	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
9	30/06/2021	RW	1.21	0.113	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
10	30/06/2021	RW	2.46	0.186	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
11	30/06/2021	RW	2.21	0.186	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
12	30/06/2021	RW	2.00	0.186	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
13	30/06/2021	RW	1.83	0.253	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
14	30/06/2021	RW	1.60	0.200	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
15	30/06/2021	RW	2.46	0.310	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
16	30/06/2021	RW	2.21	0.310	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
17	30/06/2021	RW	2.00	0.310	0.000	0.000	0	0	0	0	0.000	0.000	NA	NA	
26	02/07/2021	BiW	2.00	0.186	1.210	0.042	0	0	0	0	0.000	0.000	NA	NA	Not used in model testing
27	02/07/2021	BiW	2.00	0.186	1.420	0.054	0	0	0	0	0.000	0.000	NA	NA	Not used in model testing
28	02/07/2021	BiW	2	0.186	1.6	0.072	0	0	0	0	0.000	0.000	NA	NA	
29	02/07/2021	BiW	2	0.186	1.83	0.09	0	0	0	0	0.000	0.000	NA	NA	
30	02/07/2021	BiW	2	0.186	2.46	0.1116	0	0	0	0	0.000	0.000	NA	NA	
31	02/07/2021	BiW	1.21	0.0678	1.42	0.054	0	0	0	0	0.000	0.000	NA	NA	Not used in model testing
32	02/07/2021	BiW	1.21	0.0678	1.6	0.072	0	0	0	0	0.000	0.000	NA	NA	Not used in model testing
33	05/07/2021	BiW	1.21	0.0678	1.83	0.09	0	0	0	0	0.000	0.000	NA	NA	Not used in model testing
34	05/07/2021	BiW	1.21	0.0678	2	0.1116	0	0	0	0	0.000	0.000	NA	NA	Not used in model testing
35	05/07/2021	BiW	1.21	0.0678	2.46	0.1116	0	0	0	0	0.000	0.000	NA	NA	Not used in model testing
36	05/07/2021	BiW	1.6	0.12	1.21	0.042	0	0	0	0	0.000	0.000	NA	NA	Not used in model testing
37	05/07/2021	BiW	1.6	0.12	1.42	0.054	0	0	0	0	0.000	0.000	NA	NA	Not used in model testing
38	05/07/2021	BiW	1.6	0.12	1.83	0.09	0	0	0	0	0.000	0.000	NA	NA	
39	05/07/2021	BiW	1.6	0.12	2	0.1116	0	0	0	0	0.000	0.000	NA	NA	
40	05/07/2021	BiW	1.6	0.12	2.46	0.1116	0	0	0	0	0.000	0.000	NA	NA	
41	05/07/2021	IW	1.4	0.09	0	0	3.3	0	0	0	0.000	0.000	NA	NA	Not used in model testing
42	05/07/2021	IW	1.8	0.15	0	0	3.3	0	0	0	0.000	0.000	NA	NA	Not used in model testing
43	05/07/2021	IW	1.8	0.15	0	0	3.3	0	0	0	0.000	0.000	NA	NA	Not used in model testing
44	05/07/2021	IW	1.8	0.15	0	0	3.3	0	0	0	0.000	0.000	NA	NA	Not used in model testing
45	05/07/2021	IW	1.8	0.15	0	0	3.3	0	0	0	0.000	0.000	NA	NA	Not used in model testing
46	05/07/2021	IW	1.8	0.15	0	0	3.3	0	0	0	0.000	0.000	NA	NA	Not used in model testing
47	05/07/2021	IW	2.2	0.18	0	0	3.3	0	0	0	0.000	0.000	NA	NA	OK

Table 3-1: Wave calibration test matrix

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Test num	Date	Wave type	T/Tp(s)	H/Hs(m)	T2_s	H2_m	Gamma	Foil phase	Vrotor_Rad_sec	Added vel. Amp(deg/s)	Added vel. period (s)	Pitch1	Pitch2	Comments
0	test in air at 8deg													
48	06/07/2021	DRY	0	0	0	0	0	0	0.1	0.000	0.000	NA	8	OK
49	06/07/2021	DRY	0	0	0	0	0	0	1	0.000	0.000	NA	8	OK
50	06/07/2021	DRY	0	0	0	0	0	0	2	0.000	0.000	NA	8	OK
51	06/07/2021	DRY	0	0	0	0	0	0	5	0.000	0.000	NA	8	OK
52	06/07/2021	DRY	0	0	0	0	0	0	12	0.000	0.000	NA	8	OK
0	test in air at 0deg													
53	06/07/2021	DRY	0	0	0	0	0	0	0.1	0.000	0.000	NA	0	OK
54	06/07/2021	DRY	0	0	0	0	0	0	1	0.000	0.000	NA	0	OK
55	06/07/2021	DRY	0	0	0	0	0	0	2	0.000	0.000	NA	0	OK
56	06/07/2021	DRY	0	0	0	0	0	0	5	0.000	0.000	NA	0	OK
57	06/07/2021	DRY	0	0	0	0	0	0	12	0.000	0.000	NA	0	OK
0	No wave in water at 0deg													
58	07/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	NA	0	OK
59	07/07/2021	ZERO	0	0	0	0	0	0	1	0.000	0.000	NA	0	OK
60	07/07/2021	ZERO	0	0	0	0	0	0	2	0.000	0.000	NA	0	OK
61	07/07/2021	ZERO	0	0	0	0	0	0	5	0.000	0.000	NA	0	OK
62	07/07/2021	ZERO	0	0	0	0	0	0	12	0.000	0.000	NA	0	OK
0	No wave in water at 0deg to check acceleration times													
65	07/07/2021	ZERO	0	0	0	0	0	0	2.62	0.000	0.000	NA	0	OK
66	07/07/2021	ZERO	0	0	0	0	0	0	2.86	0.000	0.000	NA	0	OK
67	07/07/2021	ZERO	0	0	0	0	0	0	3.14	0.000	0.000	NA	0	OK
68	07/07/2021	ZERO	0	0	0	0	0	0	3.49	0.000	0.000	NA	0	OK
69	07/07/2021	ZERO	0	0	0	0	0	0	3.93	0.000	0.000	NA	0	OK
70	07/07/2021	ZERO	0	0	0	0	0	0	4.49	0.000	0.000	NA	0	OK
71	07/07/2021	ZERO	0	0	0	0	0	0	5.24	0.000	0.000	NA	0	OK
0	test with wave at expected 90 deg. Phase (rotor at 90 deg. At wave crest times)													
72	08/07/2021	RW	1.4	0.153	0	0	0	90	2.62	0.000	0.000	NA	0	Foil phase not exact
73	08/07/2021	RW	1.4	0.153	0	0	0	90	4.418	0.000	0.000	NA	0	Foil phase not exact
74	08/07/2021	RW	1.6	0.2	0	0	0	90	3.927	0.000	0.000	NA	0	Foil phase not exact
75	08/07/2021	RW	1.8	0.253	0	0	0	90	3.436	0.000	0.000	NA	0	waves didn't start
77	08/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	NA	0	Foil phase not exact
78	08/07/2021	RW	2.2	0.31	0	0	0	90	2.847	0.000	0.000	NA	0	Foil phase not exact
79	08/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	NA	0	Foil phase not exact
80	09/07/2021	RW	1.4	0.153	0	0	0	90	4.413	0.000	0.000	NA	0	test on RPM correction, noy used
0	Fairings removed to check the phase shifts on load cells													
83	12/07/2021	ZERO	0	0	0	0	0	0	1	0.000	0.000	NA	0	OK
84	12/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	NA	0	OK
85	12/07/2021	DRY	IN AIR	0	0	0	0	0	0.1	0.000	0.000	NA	0	OK
0	removed foil 2													
86	13/07/2021	0	0	0	0	0	0	0	0	0.000	0.000	0	NA	test foil1
0	foil change (removed 2 and placed 1) due to Load8 error, test with no fairings													
87	13/07/2021	DRY	IN AIR	0	0	0	0	0	0.1	0.000	0.000	0	NA	OK
88	13/07/2021	DRY	IN AIR	0	0	0	0	0	0.1	0.000	0.000	0	NA	repeat
89	13/07/2021	DRY	IN AIR	0	0	0	0	0	1	0.000	0.000	0	NA	OK
90	13/07/2021	DRY	IN AIR	0	0	0	0	0	2	0.000	0.000	0	NA	OK
91	13/07/2021	DRY	IN AIR	0	0	0	0	0	5	0.000	0.000	0	NA	OK
92	13/07/2021	DRY	IN AIR	0	0	0	0	0	12	0.000	0.000	0	NA	OK

Table 3-2: Model testing test matrix (page1/5)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Test num	Date	Wave type	T/Tp(s)	H/Hs(m)	T2_s	H2_m	Gamma	Foil phase	Vrotor_Rad_sec	Added vel. Amp(deg/s)	Added vel. period (s)	Pitch1	Pitch2	Comments
0	**FAIRINGS ADDED**													
93	13/07/2021	DRY	IN AIR	0	0	0	0	0	0.1	0.000	0.000	0	NA	OK
94	13/07/2021	DRY	IN AIR	0	0	0	0	0	1	0.000	0.000	0	NA	OK
95	13/07/2021	DRY	IN AIR	0	0	0	0	0	2	0.000	0.000	0	NA	OK
96	13/07/2021	DRY	IN AIR	0	0	0	0	0	5	0.000	0.000	0	NA	OK
98	13/07/2021	DRY	IN AIR	0	0	0	0	0	12	0.000	0.000	0	NA	OK
0	**model in water**													
99	13/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	0	NA	OK
101	15/07/2021	ZERO	0	0	0	0	0	0	1	0.000	0.000	0	NA	OK
102	15/07/2021	ZERO	0	0	0	0	0	0	2	0.000	0.000	0	NA	OK
103	15/07/2021	ZERO	0	0	0	0	0	0	5	0.000	0.000	0	NA	OK
104	15/07/2021	ZERO	0	0	0	0	0	0	12	0.000	0.000	0	NA	OK
106	15/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	0	NA	OK
107	15/07/2021	RW	1.4	0.153	0	0	0	90	4.413	0.000	0.000	0	NA	test on RPM correction, noy used
108	15/07/2021	RW	1.4	0.153	0	0	0	90	4.418	0.000	0.000	0	NA	Foil phase improved
109	15/07/2021	RW	1.6	0.2	0	0	0	90	3.927	0.000	0.000	0	NA	Foil phase improved
110	15/07/2021	RW	1.8	0.253	0	0	0	90	3.436	0.000	0.000	0	NA	Foil phase improved
111	15/07/2021	RW	2	0.31	0	0	0	90	2.142	0.000	0.000	0	NA	Foil phase improved
112	15/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	0	NA	Foil phase improved
113	15/07/2021	RW	2.2	0.31	0	0	0	90	2.847	0.000	0.000	0	NA	Foil phase improved
114	15/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	0	NA	Foil phase improved
0	**Foil 1 moved to 4 degree pitch**													
118	16/07/2021	DRY	IN AIR	0	0	0	0	0	0.1	0.000	0.000	4	NA	OK
119	16/07/2021	DRY	IN AIR	0	0	0	0	0	1	0.000	0.000	4	NA	OK
120	16/07/2021	DRY	IN AIR	0	0	0	0	0	2	0.000	0.000	4	NA	OK
121	16/07/2021	DRY	IN AIR	0	0	0	0	0	5	0.000	0.000	4	NA	OK
122	16/07/2021	DRY	IN AIR	0	0	0	0	0	12	0.000	0.000	4	NA	OK
0	**placing model in water**													
123	16/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	4	NA	OK
124	16/07/2021	ZERO	0	0	0	0	0	0	1	0.000	0.000	4	NA	OK
125	16/07/2021	ZERO	0	0	0	0	0	0	2	0.000	0.000	4	NA	OK
126	16/07/2021	ZERO	0	0	0	0	0	0	5	0.000	0.000	4	NA	OK
127	16/07/2021	ZERO	0	0	0	0	0	0	12	0.000	0.000	4	NA	OK
128	16/07/2021	RW	1.4	0.153	0	0	0	90	4.418	0.000	0.000	4	NA	OK
129	16/07/2021	RW	1.6	0.2	0	0	0	90	3.927	0.000	0.000	4	NA	OK
130	16/07/2021	RW	1.8	0.253	0	0	0	90	3.436	0.000	0.000	4	NA	problem with friction

Table 3-3: Model testing test matrix (page 2/5)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Test num	Date	Wave type	T/Tp(s)	H/Hs(m)	T2_s	H2_m	Gamma	Foil phase	Vrotor_Rad_sec	Added vel. Amp(deg/s)	Added vel. period (s)	Pitch1	Pitch2	Comments
0	**removed the model and tightened the fairings**													
132	16/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	4	NA	OK
133	16/07/2021	ZERO	0	0	0	0	0	0	1	0.000	0.000	4	NA	OK
134	16/07/2021	ZERO	0	0	0	0	0	0	2	0.000	0.000	4	NA	OK
135	16/07/2021	ZERO	0	0	0	0	0	0	5	0.000	0.000	4	NA	OK
136	16/07/2021	ZERO	0	0	0	0	0	0	12	0.000	0.000	4	NA	OK
138	16/07/2021	RW	1.2	0.113	0	0	0	90	5.203	0.000	0.000	4	NA	phase shift is wrong
140	16/07/2021	RW	1.2	0.113	0	0	0	90	5.203	0.000	0.000	4	NA	OK
141	16/07/2021	RW	1.4	0.153	0	0	0	90	4.418	0.000	0.000	4	NA	OK
142	16/07/2021	RW	1.6	0.2	0	0	0	90	3.927	0.000	0.000	4	NA	OK
143	16/07/2021	RW	1.8	0.253	0	0	0	90	3.436	0.000	0.000	4	NA	OK
144	16/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	4	NA	video started too late
145	16/07/2021	RW	2.2	0.31	0	0	0	90	2.847	0.000	0.000	4	NA	OK
146	16/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	4	NA	OK
149	19/07/2021	ZERO	0	0	0	0	0	0	3.927	12.272	2.560	4	NA	OK
150	19/07/2021	ZERO	0	0	0	0	0	0	3.142	21.206	1.481	4	NA	OK
151	19/07/2021	ZERO	0	0	0	0	0	0	3.142	9.817	3.200	4	NA	OK
152	19/07/2021	ZERO	0	0	0	0	0	0	1.571	4.909	6.400	4	NA	OK
154	19/07/2021	RW	2	0.31	0	0	0	45	3.142	0.000	0.000	4	NA	OK
155	19/07/2021	RW	2	0.31	0	0	0	60	3.142	0.000	0.000	4	NA	OK
156	19/07/2021	RW	2	0.31	0	0	0	70	3.142	0.000	0.000	4	NA	OK
157	19/07/2021	RW	2	0.31	0	0	0	110	3.142	0.000	0.000	4	NA	Torque overload, test stopped
158	19/07/2021	RW	2	0.31	0	0	0	110	3.142	0.000	0.000	4	NA	OK
159	19/07/2021	RW	2	0.31	0	0	0	135	3.142	0.000	0.000	4	NA	Torque overload, test stopped
160	19/07/2021	RW	2	0.31	0	0	0	135	3.142	0.000	0.000	4	NA	OK
161	19/07/2021	ZERO	0	0	0	0	0	0	3.142	0.000	0.000	4	NA	OK
0	**changed pitch to -4 deg**													
162	19/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	-4	NA	OK
164	19/07/2021	ZERO	0	0	0	0	0	0	1	0.000	0.000	-4	NA	OK
165	19/07/2021	ZERO	0	0	0	0	0	0	2	0.000	0.000	-4	NA	OK
166	19/07/2021	ZERO	0	0	0	0	0	0	3.142	0.000	0.000	-4	NA	0
167	19/07/2021	ZERO	0	0	0	0	0	0	3.927	0.000	0.000	-4	NA	OK
169	19/07/2021	ZERO	0	0	0	0	0	0	12	0.000	0.000	-4	NA	OK
170	19/07/2021	ZERO	0	0	0	0	0	0	3.142	9.817	3.200	-4	NA	OK
171	19/07/2021	ZERO	0	0	0	0	0	0	2.553	0.000	0.000	-4	NA	OK
172	19/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	-4	NA	OK
0	**changed pitch to -8 deg**													
173	19/07/2021	ZERO	0	0	0	0	0	0	3.142	9.817	3.200	-8	NA	OK
174	19/07/2021	ZERO	0	0	0	0	0	0	3.142	0.000	0.000	-8	NA	OK
175	20/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	-8	NA	OK
0	**changed pitch to -4 deg**													
176	20/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	-4	NA	OK
177	20/07/2021	ZERO	0	0	0	0	0	0	3.142	0.000	0.000	-4	NA	OK
178	20/07/2021	ZERO	0	0	0	0	0	0	5	0.000	0.000	-4	NA	OK

Table 3-4: Model testing test matrix (page 3/5)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Test num	Date	Wave type	T/Tp(s)	H/Hs(m)	T2_s	H2_m	Gamma	Foil phase	Vrotor_Rad_sec	Added vel. Amp(deg/s)	Added vel. period (s)	Pitch1	Pitch2	Comments
0	**ADDING foil 2 @ 0deg pitch**													
180	20/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	0	0	touching fairing
181	20/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	0	0	OK
182	20/07/2021	ZERO	0	0	0	0	0	0	1	0.000	0.000	0	0	OK
183	20/07/2021	ZERO	0	0	0	0	0	0	3.142	0.000	0.000	0	0	OK
185	20/07/2021	ZERO	0	0	0	0	0	0	5	0.000	0.000	0	0	OK
186	20/07/2021	ZERO	0	0	0	0	0	0	12	0.000	0.000	0	0	OK
187	20/07/2021	RW	1.8	0.253	0	0	0	90	3.436	0.000	0.000	0	0	OK
188	20/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	0	0	OK
189	20/07/2021	RW	2.2	0.31	0	0	0	90	2.847	0.000	0.000	0	0	Rotor did not engage
190	20/07/2021	RW	2.2	0.31	0	0	0	90	2.847	0.000	0.000	0	0	OK
191	20/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	0	0	OK
192	20/07/2021	RW	2.4	0.31	0	0	0	NA	free	0.000	0.000	0	0	Free wheeling for zero speed then motored to constant speed followed by free wheeling
193	21/07/2021	ZERO	0	0	0	0	0	90	1.047	0.000	0.000	0	0	OK
195	21/07/2021	ZERO	0	0	0	0	0	90	1.571	0.000	0.000	0	0	OK
196	21/07/2021	ZERO	0	0	0	0	0	90	2.095	0.000	0.000	0	0	OK
197	21/07/2021	ZERO	0	0	0	0	0	90	4.189	0.000	0.000	0	0	OK
198	21/07/2021	ZERO	0	0	0	0	0	90	4.713	0.000	0.000	0	0	OK
199	21/07/2021	ZERO	0	0	0	0	0	90	6.284	0.000	0.000	0	0	OK
201	21/07/2021	RW	2	0.31	0	0	0	90	1.047	0.000	0.000	0	0	OK
203	21/07/2021	RW	2	0.31	0	0	0	90	1.571	0.000	0.000	0	0	OK
204	21/07/2021	RW	2	0.31	0	0	0	90	2.095	0.000	0.000	0	0	Wavemaker error
205	21/07/2021	RW	2	0.31	0	0	0	90	2.095	0.000	0.000	0	0	error in phase angle
206	21/07/2021	RW	2	0.31	0	0	0	90	2.095	0.000	0.000	0	0	OK
208	21/07/2021	RW	2	0.31	0	0	0	90	4.189	0.000	0.000	0	0	OK
209	21/07/2021	RW	2	0.31	0	0	0	90	4.713	0.000	0.000	0	0	OK
210	21/07/2021	RW	2	0.31	0	0	0	90	6.284	0.000	0.000	0	0	OK
211	21/07/2021	IW	2.2	0.18	0	0	0	0	4.418	0.000	0.000	0	0	OK
212	21/07/2021	IW	2.2	0.18	0	0	0	0	4.418	0.000	0.000	0	0	OK
213	21/07/2021	IW	2.2	0.18	0	0	0	0	4.418	0.000	0.000	0	0	OK
214	21/07/2021	IW	2.2	0.18	0	0	0	0	4.418	0.000	0.000	0	0	Rotor interrupted during run probable overspeed error
215	21/07/2021	IW	2.2	0.18	0	0	0	0	4.418	0.000	0.000	0	0	OK
216	21/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	0	0	repeat test

Table 3-5: Model testing test matrix (page 4/5)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

Test num	Date	Wave type	T/Tp(s)	H/Hs(m)	T2_s	H2_m	Gamma	Foil phase	Vrotor_Rad_sec	Added vel. Amp(deg/s)	Added vel. period (s)	Pitch1	Pitch2	Comments
0	**changed pitch to 1 @ -4deg and 2 @ 4deg**													
219	21/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	-4	4	OK
220	21/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	-4	4	OK
221	21/07/2021	ZERO	0	0	0	0	0	0	1	0.000	0.000	-4	4	OK
222	21/07/2021	ZERO	0	0	0	0	0	0	2	0.000	0.000	-4	4	OK
223	21/07/2021	ZERO	0	0	0	0	0	0	5	0.000	0.000	-4	4	OK
225	21/07/2021	RW	1.4	0.153	0	0	0	90	4.418	0.000	0.000	-4	4	OK
226	21/07/2021	RW	1.6	0.2	0	0	0	90	3.927	0.000	0.000	-4	4	OK
227	21/07/2021	RW	1.8	0.253	0	0	0	90	3.436	0.000	0.000	-4	4	OK
228	21/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	-4	4	video started too late
229	21/07/2021	RW	2.2	0.31	0	0	0	90	2.847	0.000	0.000	-4	4	OK
230	22/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	-4	4	OK
231	22/07/2021	BiW	2	0.186	1.6	0.072	1.6	90	3.142	0.000	0.000	-4	4	OK
232	22/07/2021	BiW	2	0.186	1.8	0.09	1.6	90	3.142	0.000	0.000	-4	4	OK
234	22/07/2021	BiW	2	0.186	2.4	0.1116	1.6	90	3.142	0.000	0.000	-4	4	OK
235	22/07/2021	RW	1.8	0.253	0	0	0	45	3.436	0.000	0.000	-4	4	touching fairing
236	22/07/2021	RW	1.8	0.253	0	0	0	45	3.436	0.000	0.000	-4	4	OK
237	22/07/2021	RW	1.8	0.253	0	0	0	70	3.436	0.000	0.000	-4	4	OK
238	22/07/2021	RW	1.8	0.253	0	0	0	90	3.436	0.000	0.000	-4	4	OK
239	22/07/2021	RW	1.8	0.253	0	0	0	110	3.436	0.000	0.000	-4	4	OK
240	22/07/2021	RW	1.8	0.253	0	0	0	135	3.436	0.000	0.000	-4	4	OK
241	22/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	-4	4	OK
242	22/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	-4	4	Constant speed then switch to free wheeling to see if the system can be driven by waves.
0	**changed pitch to 1 @ 4deg and 2 @ -4deg**													
243	22/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	4	-4	OK
244	22/07/2021	BiW	1.6	0.12	1.8	0.09	0	90	3.927	0.000	0.000	4	-4	OK
245	22/07/2021	BiW	1.6	0.12	2	0.1116	0	90	3.927	0.000	0.000	4	-4	OK
246	22/07/2021	BiW	1.6	0.12	2.4	0.1116	0	90	3.927	0.000	0.000	4	-4	OK
0	00/01/1900	0	0	0	0	0	0	0	0	0.000	0.000	0	0	0
247	22/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	4	-4	Constant speed then switch to free wheeling to see if the system can be driven by waves.
0	**changed pitch to 1 @ -8deg and 2 @ 8deg**													
248	23/07/2021	RW	1.8	0.253	0	0	0	90	3.436	0.000	0.000	-8	8	OK
249	23/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	-8	8	OK
250	23/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	-8	8	OK
251	23/07/2021	RW	2.2	0.31	0	0	0	90	2.847	0.000	0.000	-8	8	OK
252	23/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	-8	8	OK
253	23/07/2021	RW	2.2	0.31	0	0	0	90	2.847	0.000	0.000	-8	8	OK
254	23/07/2021	RW	2.2	0.31	0	0	0	90	2.847	0.000	0.000	-8	8	OK
255	23/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	-8	8	OK
256	23/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	-8	8	OK
0	**changed pitch to 1 @ -4deg and 2 @ 4deg**													
257	23/07/2021	ZERO	0	0	0	0	0	0	0.1	0.000	0.000	-4	4	OK
258	23/07/2021	BiW	2	0.186	1.8	0.09	1.6	90	3.142	0.000	0.000	-4	4	OK
259	23/07/2021	BiW	2	0.186	1.8	0.09	1.6	90	3.142	0.000	0.000	-4	4	OK
260	23/07/2021	RW	2	0.31	0	0	0	90	3.142	0.000	0.000	-4	4	OK
261	23/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	4	-4	OK
262	23/07/2021	RW	2.4	0.31	0	0	0	90	2.553	0.000	0.000	4	-4	OK

Table 3-6: Model testing test matrix (page 5/5)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

4 DATA ANALYSIS

4.1 MERGED DATA FILE GENERATION

After testing, a Matlab code developed by ECN was used to merge the two data files into a single Matlab file including all the calibrated parameters sampled at 128 Hz and in SI units. The two files were synchronised using an electrical trigger from the wavemaker with a rising edge at the start of wave generation. It generated for each test a Matlab file named with a Matlab structure that contains the following elements:

- "date": test date in Matlab number format
- "data": test data with one column per parameter
- "Time": time column corresponding to the "data" table. In this column, zero value corresponds to the first time step in which the wavemaker trigger value is high, which means the wavemaker is starting.
- "chanNames": name of the header for each column in the "data" table.
- "chanUnits": SI units corresponding to each column in the "data" table.
- "testnum": Test number corresponding to the list of tests in the test matrix section 3.2
- "family": All sensors are sorted in families to simplify the analysis with the ECN Matlab code. This may not be required for further analysis
- "II": This element is used in the ECN Matlab code to find a column in the "data" element corresponding to a given sensor. This may not be required for further analysis
- "type": This element is used in the ECN Matlab code to choose the type of analysis to be done for each test. This may not be required for further analysis

During wave calibration, the list of channels in the data elements and listed in "chanNames" are:

- 2 columns with wavemaker trigger in binary format and in Volts. These column are not needed for further analysis, they were used to synchronise the data files.
- "WGx: 11 columns with Wave gauges (WG) 1 to 11 measurement in meter. "x" is the wave gauge number.

During model testing, the list of channels in the data elements and listed in "chanNames" are:

- 2 columns with wavemaker trigger in binary format and in Volts. These columns are not needed for further analysis, they were used to synchronise the data files.
- "WGx": 11 columns with Wave gauges (WG) measurements in meter (WG5 was removed and the WG5 data should not be used). X is the wave gauge number.
- "Fx": 8 columns with force measurement (F) in Newton from the 8 load cells on the model. "x" is the load cell number.
- "Speed": The rotor speed in radian per second
- "Motortorque_Cor": The motor estimated torque in Newton meter.
- "Torquemeter_Cor": The torque measured at the torque meter in Newton meter.
- "Cpt_position_aux": The rotor position in degree.

Details on the instrumentation and acquisition system are in section 2.3 and 2.4.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

The name of the merged file for each test is “LIFTWEC_XXX.mat”, with XXX the test number described in the test matrix.

Actions in the pre-processing:

- Open both raw data files generated by the two acquisition systems, the CRio and Quantum.
- Select channels that need to be save for data analysis
- Resample the timeseries at the desired acquisition rate of 128Hz for this project.
- Find the rising edge of the wavemaker trigger signal in both data files and change the time reference to zero value at the corresponding line in the time series

4.2 LOAD AND TORQUE ZEROING

The load and torque sensors measure the static loads due to the weight of rotor parts they are connected to and this varies with the rotor position. Therefore, it is not possible to apply a simple offset for the whole duration of a test, the sensor offset must be calculated and removed from the measurement times series in post processing. This was done in two phases:

- Calculation of the static load and torque curve versus rotor angular position for tests with a slow and constant velocity of 0.1 rad/sec. This test was done for most configurations, in water or in the dry. The data is analysed for each sensor and for multiple rotations and sorted based on the angular position between 0 and 360 degrees. The zero curve is then calculated using the Matlab default linear interpolation function “interp1” on the sorted sensor measurement versus angular position. The interpolated curve gives a value each 0.2 degree, from 0 to 360 degrees. A static load curve is shown as an example in Figure 4-1.
- Removing the static load and torque values from measurements for each relevant columns in each data file.

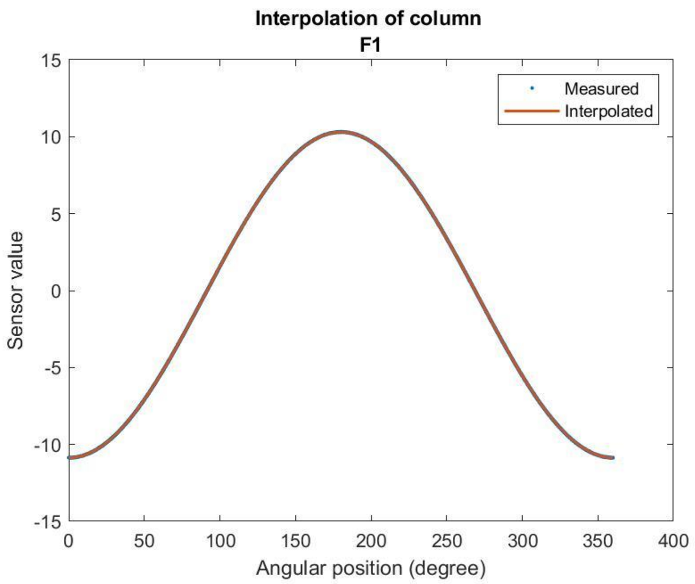


Figure 4-1: Example of zero reference curve measure in test 48 on load cell 1

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

4.3 CENTRIFUGAL FORCE COMPENSATION

The rotation of the rotor results in a centrifugal force on the load cells and it was decided, after zeroing all channels, to remove the centrifugal force component of the load measured so that the corrected load in the data file corresponds as close as possible to the hydrodynamic forces applied on the foils to make it easier for comparison with numerical models.

The centrifugal force is defined in Equation 1 with the mass in rotation "m" in kilogrammes connected to the load cell, the rotor rotational speed "ω" in rad/sec and the radius "R" between the centre of rotation and the centre of gravity of the mass "m" in metres. The rotation speed time series is measured for each test and the radius is 0.3m.

Equation 1: $F_{cent} = m * \omega^2 * R$

The mass connected to the sensors depends on whether radial or tangential measurements are considered. The load cells measuring radial forces are holding the foil but also the other load cells, measuring the tangential forces. Therefore, the value of the rotating mass and the position of its centre of gravity are not known accurately. It is however unlikely that the direction of the centrifugal force, which goes from the centre of rotation to the centre of gravity, is exactly aligned with the sensor radial direction. The centrifugal force therefore has not only components in the direction of the radial sensor but also in the direction of the tangential sensor. These two components were calculated from experimental results of tests 94 to 98 with constant speed rotation outside water. After zeroing the channels, as described in section 4.2, the force applied to the load cells is only the centrifugal force. This method gives a mass of 7.25 kg associated with radial direction and 0.93 kg associated with the tangential direction. The results are given in Table 4-1. The result of test 94, at 1 rad/sec, was discarded because it is inconsistent with other results associated with different rotational speeds. It is likely to be less accurate because it is associated with a small angular velocity and very low loads, which are proportional to the angular velocity squared. These masses were then used to calculate and remove the centrifugal force applied on each sensor.

TestNum	w(rad/sec)	Radial force (N)	Radial mass (kg)	Tang. Force (N)	Tang mass (kg)
94	1	2.2	7.43	0.3	0.86
95	2	9.0	7.51	1.1	0.93
96	5	56.5	7.53	7.0	0.93
98	12	325.4	7.54	40.1	0.93
	Average		**7.52**		**0.93**

Table 4-1: Calculation of the mass required to create centrifugal force measured in each test in air at constant speed

4.4 MERGED AND PROCESSED DATA FILES

The merged data files, described in section 4.1 were completed with the load and torque zeroing and the deduction of the centrifugal force on the load cells described in section 4.2 and 4.3.

The list of additional channels in the "data" elements and listed in "chanNames" are:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

- "Fx_Cor": 8 columns with force measurement, adjusted by removing the zero values and the centrifugal force. "x" is the load cell number
- "Motortorque_Cor": The motor estimated torque in Newton meter adjusted by removing the zero values.
- "Torquemeter_Cor": The torque measured in Newton meter at the torque meter adjusted by removing the zero values

Details on the instrumentation and acquisition system are in section 2.3 and 2.4.

The name of the merged file for each test is "LIFTWEC_XXX_CorSC.mat", with XXX the test number described in the test matrix.

These processed files were published in Zenodo under DOI: https://doi.org/10.5281/zenodo.5596066 and are now free to access. This dataset replaces the initial dataset, published under DOI: https://doi.org/10.5281/zenodo.5534471, which does not include processed data.

4.5 Motor torque variations

Large variations were observed on the torque measurements at a different period than the wave period or one of its harmonics. An example is shown in Figure 4-2.

This is an artefact of the speed control algorithm targeting a constant rotational speed of a rotor with a large inertia (3.98 kg.m2 outside water). The speeds variations are small, generally under +/- 0.1 rad/sec, as shown in Figure 4-3 and Figure 4-4 but have the same frequency as the torque oscillations.

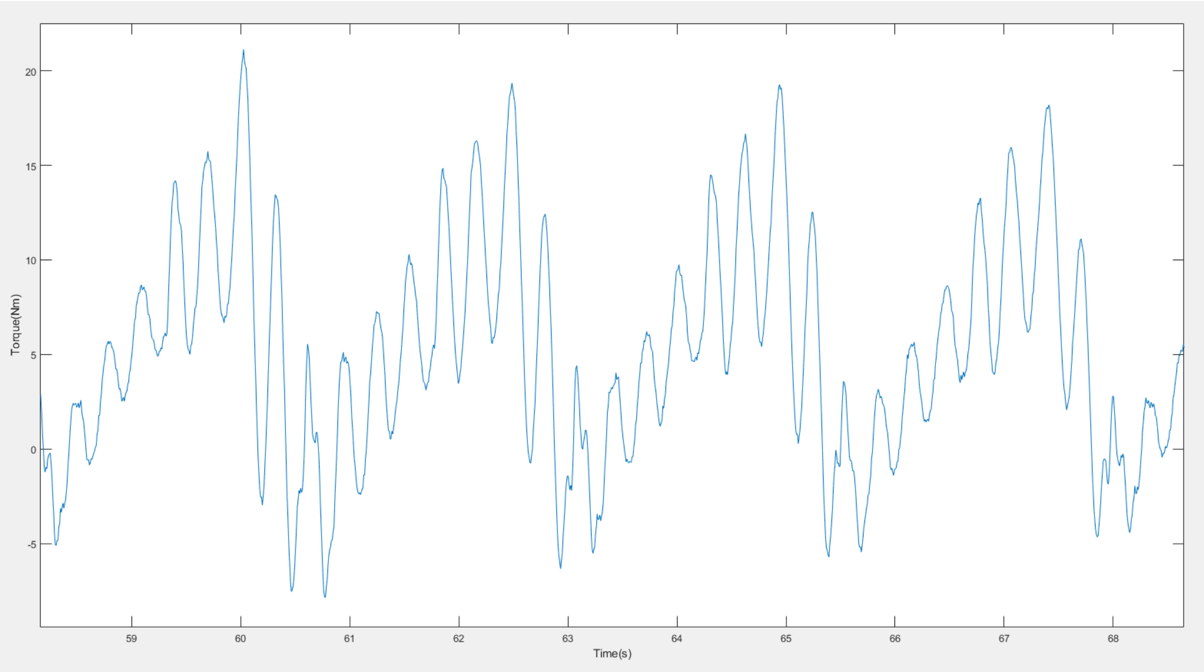


Figure 4-2: Example of torque variations observed in a regular wave test, number 114

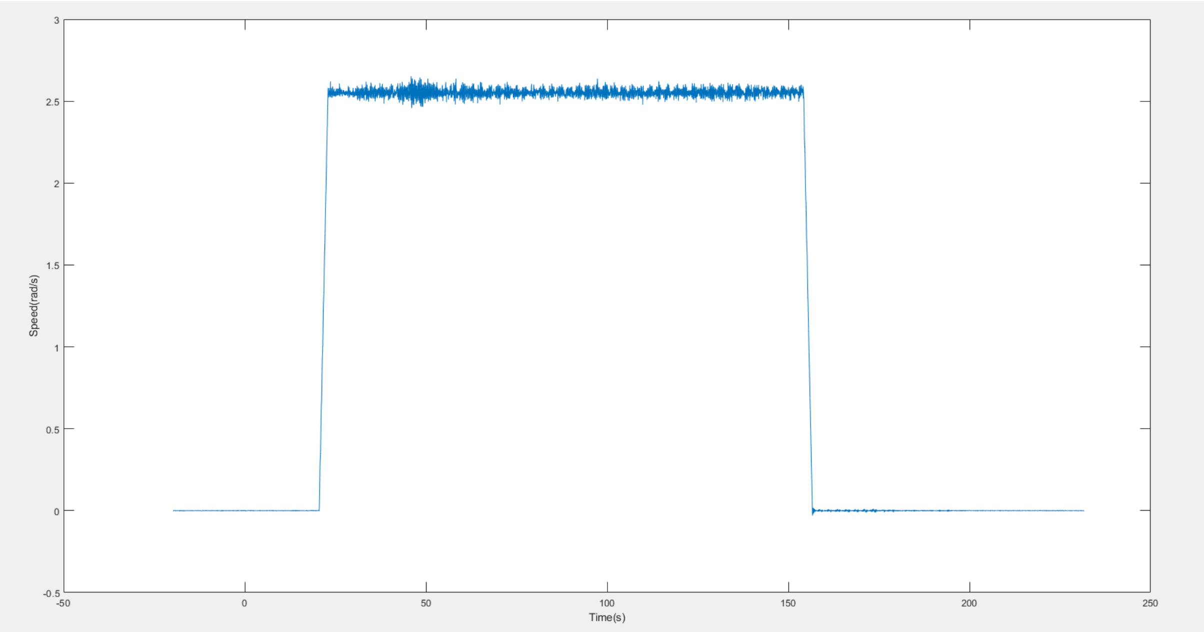


Figure 4-3: Example of speed time series (test 114)

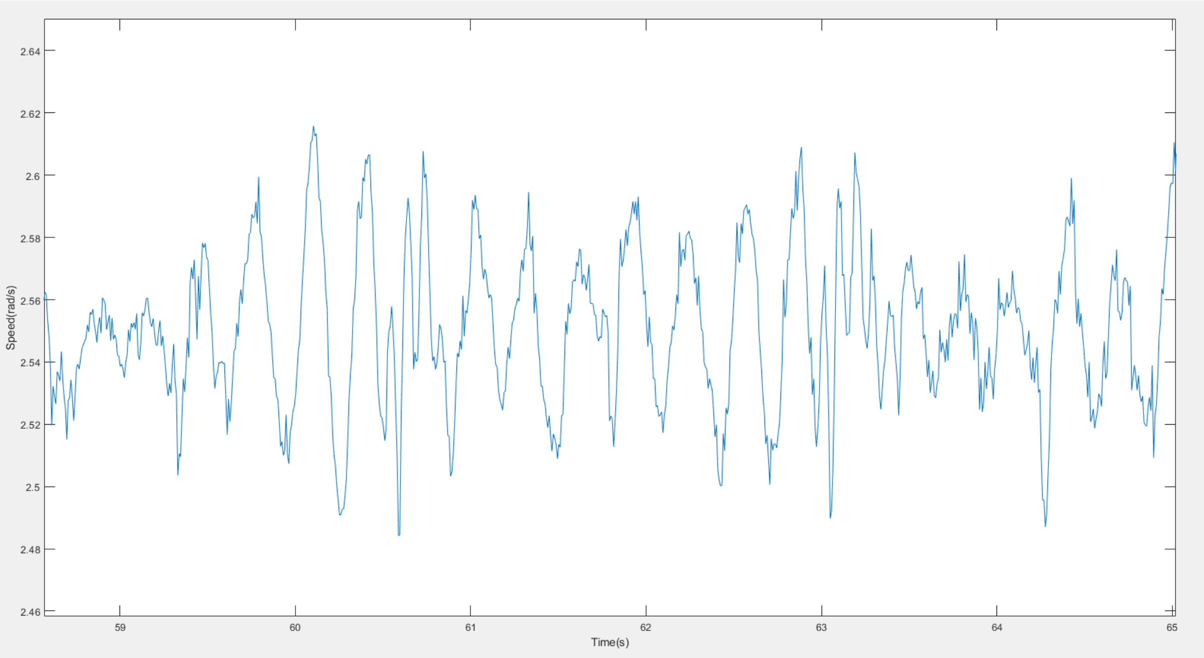


Figure 4-4: Example of speed time series focusing on small variations (test 114)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

5 LESSONS LEARNT AND DELAYS

When manufacturing and testing a bespoke experimental model, it is rare not to experience some unplanned situations, especially when the model is associated with a novel concept. In this test programme we did experience some issues, which impacted on the original schedule and test plan. The main issues are described in the following sections.

5.1 WAVE REFLECTION IN THE SUBCHANNEL

As explained above and in LiftWEC deliverable LW-04-01 on the 2D model design, the subchannel was necessary to narrow down the width of the flume (so that the loads on the model remained manageable) while making the most of the large wave generation capacity of the towing tank to test in as high Reynolds numbers as possible. We did anticipate some parasitic waves being created at the inlet and the outlet of the subchannel but we did not expect them to be significant. This was indeed the case at the inlet however, when the waves exited the subchannel at its outlet, there was a significant level of reflection that we did not anticipate. We believe that this was due to the discontinuity between the wave field inside the subchannel and the one outside. Those reflections degraded the quality of the waves inside the subchannel and also prevented us from testing in larger bi-chromatic waves because the superposition of the incident and reflected waves created at anti-nodes wave crests were higher than the walls of the subchannel. This is illustrated for a regular wave in Figure 5-1 which shows the timeseries recorded by wave gauge number 5. It can be seen that from about T = 95 s, the wave elevation measurement is affected by the wave reflected off the outlet of the subchannel. For future reference, a possible way to alleviate this problem would be to implement a beach at the outlet of the subchannel to avoid reflection. This solution is nevertheless unlikely to be straightforward as the beach also needs to be porous to avoid water level increase in the subchannel compared to the surrounding flume.

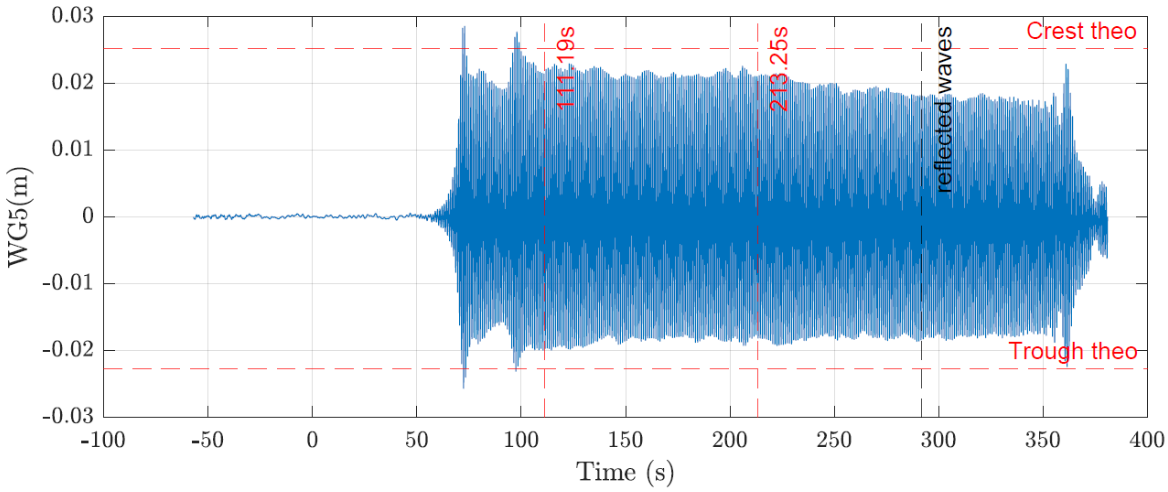


Figure 5-1: Wave elevation timeseries

5.2 ROTOR ARM FAIRINGS STIFFNESS

Fairings were designed to mask the arms of the rotor and to ensure that the foils are subjected to 2D flow conditions. Those fairings have the appearance of discs, 100mm thick and whose diameter is that

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

of the rotor. They can be seen in white on Figure 2-5. In order to limit their inertia, those disc fairings were made of polystyrene sandwiched between two GRP plates, one on each face. The fairings were fastened to the rotor arm using M4 screws but only through one of the GRP plates. FEA analysis had been carried out at design stage to make sure that the fairings would not deflect significantly under hydrostatic loads. However, it turned out that they exhibited significant deflection due to the mismatch of the wave elevation inside and the outside of the subchannel, which led to a differential pressure higher than expected. The clearance between the fairing and the foils was kept minimum (a few millimetres) so that the flow experienced by the foil is as two-dimensional as possible.

One of the consequences of the fairing's deflection is that for some tests and during part of the rotation cycle, the fairings touched the trailing edge of one of the foils, generating significant parasitic readings on the foil loadcells, which should be avoided in data analysis. This phenomenon can be observed on the recorded data and was indicated in the test matrix, when observed during testing. This problem could likely be addressed by redesigning the fastening arrangement between the arm and the fairings, to make it stiffer.

5.3 Delays

The LiftWEC 2D model test campaign was hit by several delays which ended up having a significant impact on its schedule and test programme.

The main source of delay was the Covid 19 pandemic and its consequences. This impacted the project in several ways. In spring 2020, ECN was closed for almost 3 months, with the technicians and model designers sent home. This meant that during that period, no design work could be carried out on the LiftWEC 2D model. When ECN reopened, there was not only a backlog of experimental projects to deal with but also the projects scheduled for after this first lockdown, which limited further the availability of the ECN staff to work on the LiftWEC project. Finally, the pandemic and possibly the blockage of the Suez Canal had an impact on raw material availability (mainly aluminium for us) which delayed the delivery of key parts of the model by our subcontractors.

During the tank test itself and its preparation, we were delayed by a faulty loadcell, which we had to replace and rewire as well as staffing issues.

5.4 Impact of 2D model testing issues

During the design, manufacturing and testing course of the project, we have always discussed with the other project partners the technical upheaval, the delays and there implications so that we could decide as a consortium of the best way forward in terms of schedule and test programme. One of the main consequences of those delays and technical issues is that we had to reduce the number of tests and we therefore made the decision, as a consortium, to test with a versatile model at only one rotor diameter (despite the fact that the model was designed so that it could be tested with three different diameters). The main reason for testing different diameters was for the foil to experience different levels of wave induced velocity and this was partly compensated by testing at one rotor radius but with different wave amplitude and periods. Notwithstanding this reduction in the data available, the model tests have provided sufficient data for the validation of the LiftWEC numerical models, which was the principal objective of this test programme.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

6 APPENDICES

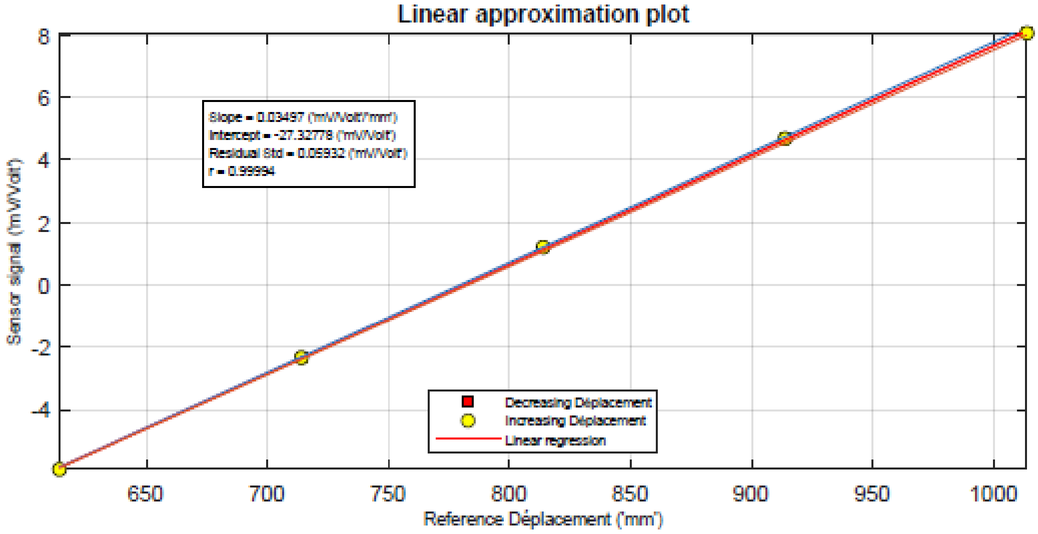
A. WAVE GAUGES CALIBRATION RESULTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

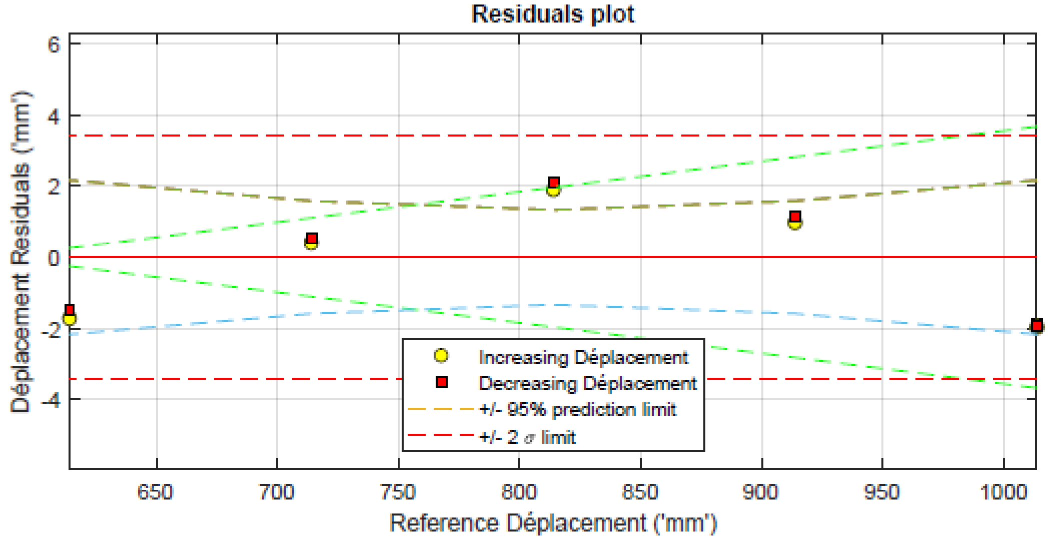
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'Laboratoire'	'Banc Etal sonde à houle WDS1000'
Sensor Name: 'WG1'	Acquisition device: 'Quantum'
Sensor Reference: 'WG1'	5 points (5 Sec @100Hz)
Full Range:600 'mm'	2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



Sensitivity = 28.594 ('mm'/'mV/Volt')	Residual Std = 1.696 'mm'
Intercept = 781.407 ('mm')	Coverage factor = 2
Linearity = 0.51 (%FS)	Expanded uncertainty = 3.39 'mm'
Hysteresis = 0.05 (%FS)	Signal Stdev = 0.002 (%FS)
Repetability = 0.02 (%FS)	

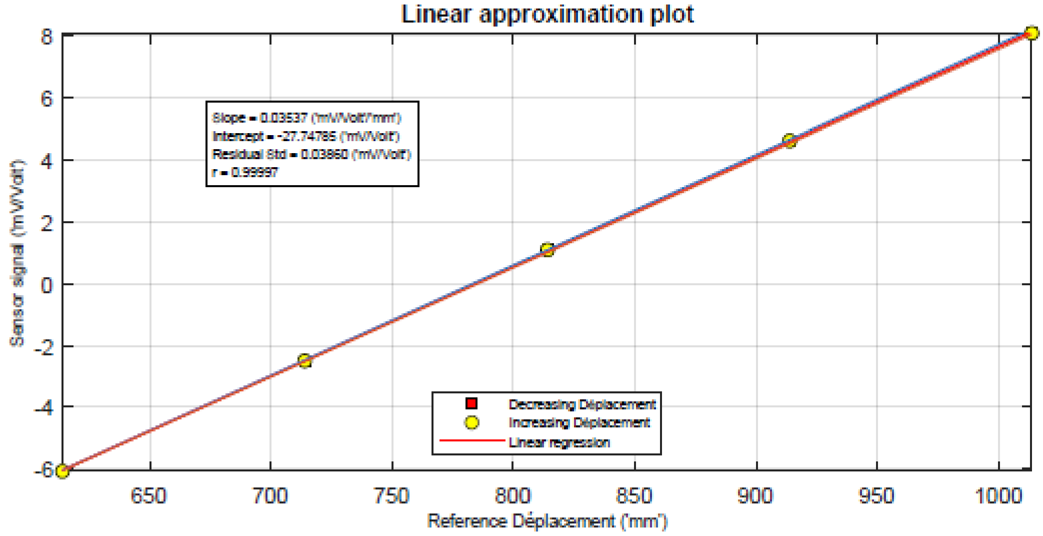
Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

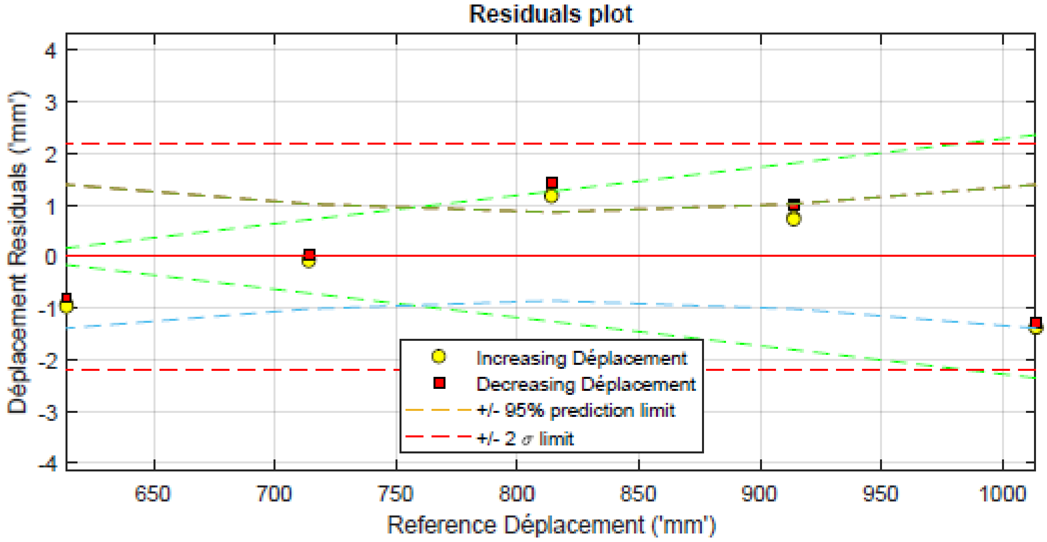
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'Laboratoire'	'Banc Etal sonde à houle WDS1000'
Sensor Name: 'WG2'	Acquisition device: 'Quantum'
Sensor Reference: 'WG2'	5 points (5 Sec @100Hz)
Full Range:600 'mm'	2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



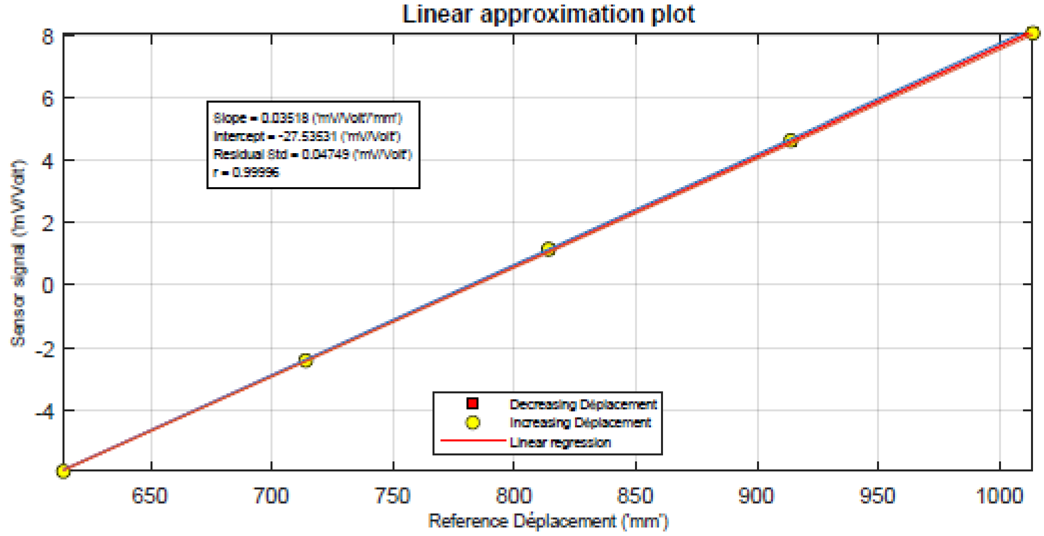
Sensitivity = 28.275 ('mm'/'mV/Volt')	Residual Std = 1.091 'mm'
Intercept = 784.577 ('mm')	Coverage factor = 2
Linearity = 0.36 (%FS)	Expanded uncertainty = 2.18 'mm'
Hysteresis = 0.07 (%FS)	Signal Stdev = 0.002 (%FS)
Repetability = 0.01 (%FS)	

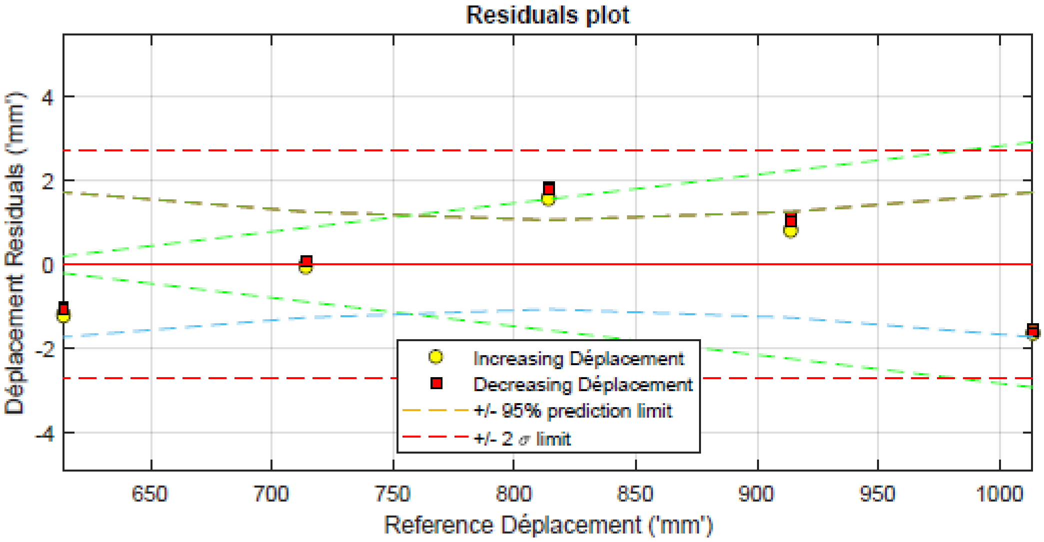
Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'Laboratoire'	'Banc Etal sonde à houle WDS1000'
Sensor Name: 'WG3'	Acquisition device: 'Quantum'
Sensor Reference: 'WG5'	5 points (5 Sec @100Hz)
Full Range:600 'mm'	2 Cycle(s) (advance & return)





Sensitivity = 28.425 ('mm'/'mV/Volt')	Residual Std = 1.350 'mm'
Intercept = 782.701 ('mm')	Coverage factor = 2
Linearity = 0.45 (%FS)	Expanded uncertainty = 2.70 'mm'
Hysteresis = 0.06 (%FS)	Signal Stdev = 0.002 (%FS)
Repetability = 0.02 (%FS)	

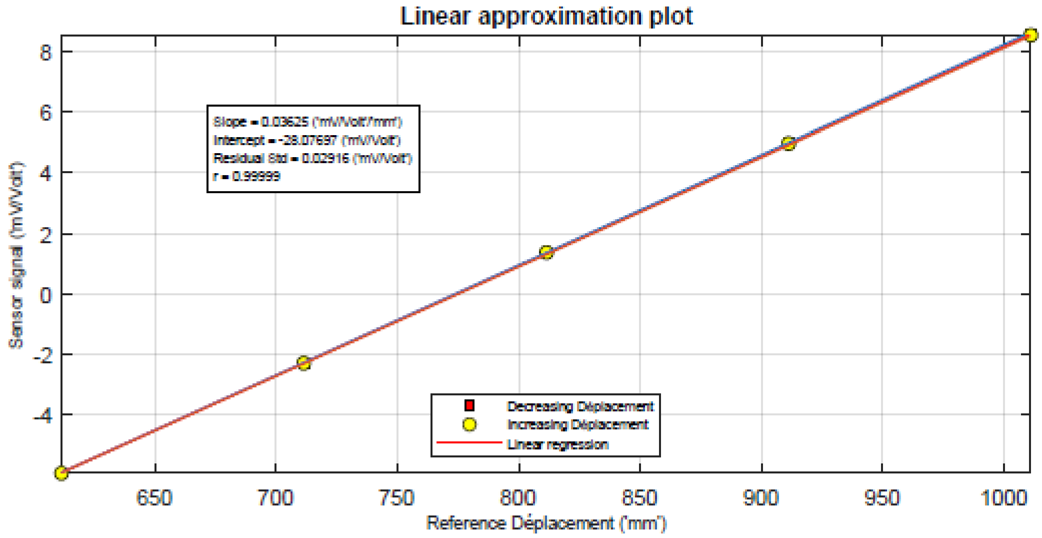
Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

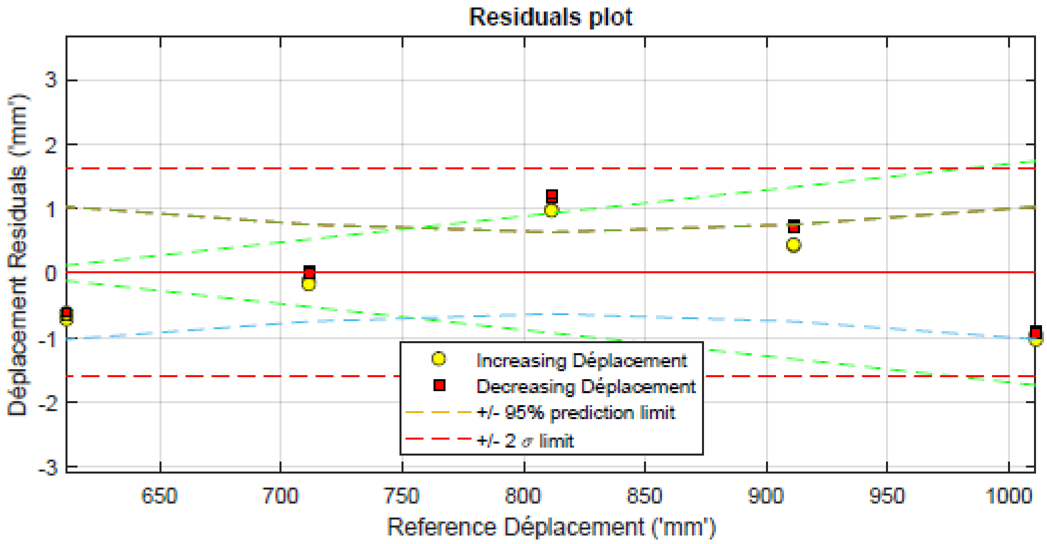
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'
Manufacturer: 'Laboratoire'
Sensor Name: 'WG4'
Sensor Reference: 'WG6'
Full Range:600 'mm'

Calibration reference standard:
'Banc Etal sonde à houle WDS1000'
Acquisition device: 'Quantum'
5 points (5 Sec @100Hz)
2 Cycle(s) (advance & return)





Sensitivity = 27.585 ('mm'/'mV/Volt')
Intercept = 774.495 ('mm')
Linearity = 0.31 (%FS)
Hysteresis = 0.07 (%FS)
Repetability = 0.02 (%FS)

Residual Std = 0.804 'mm'
Coverage factor = 2
Expanded uncertainty = 1.61 'mm'
Signal Stdev = 0.002 (%FS)

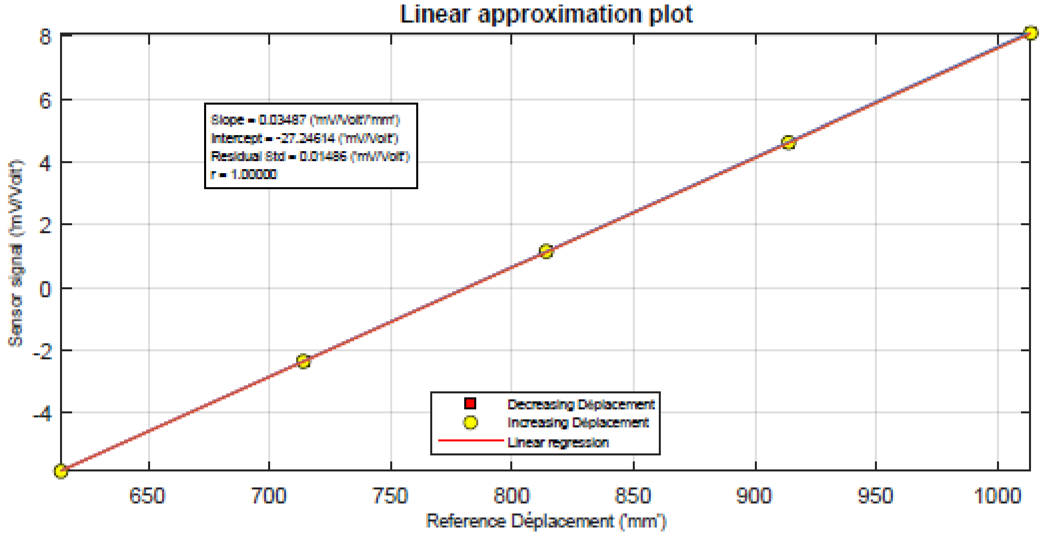
Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

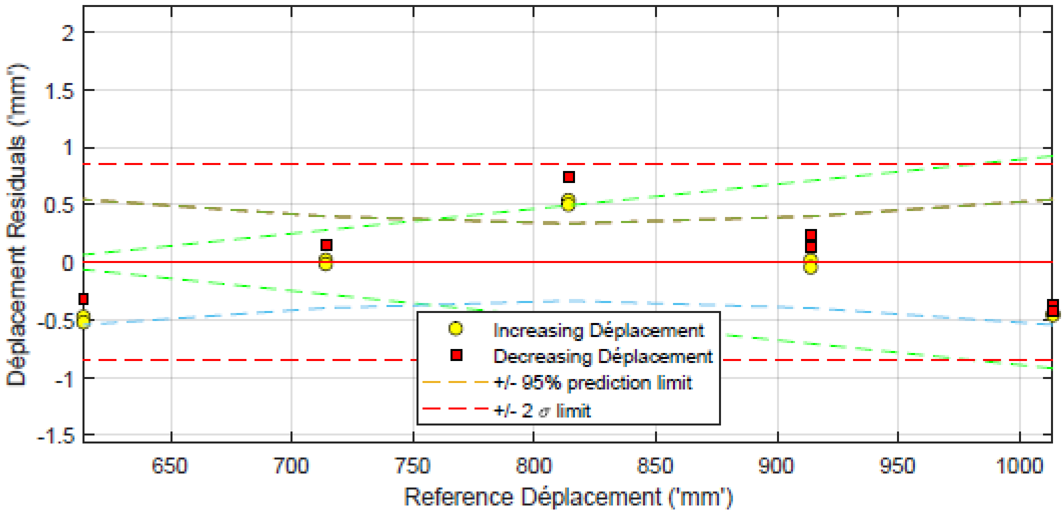
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'Laboratoire'	'Banc Etal sonde à houle WDS1000'
Sensor Name: 'WG5'	Acquisition device: 'Quantum'
Sensor Reference: 'WG7'	5 points (5 Sec @100Hz)
Full Range:600 'mm'	2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



Sensitivity = 28.676 ('mm'/'mV/Volt')	Residual Std = 0.426 'mm'
Intercept = 781.313 ('mm')	Coverage factor = 2
Linearity = 0.19 (%FS)	Expanded uncertainty = 0.85 'mm'
Hysteresis = 0.05 (%FS)	Signal Stdev = 0.002 (%FS)
Repetability = 0.03 (%FS)	

Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

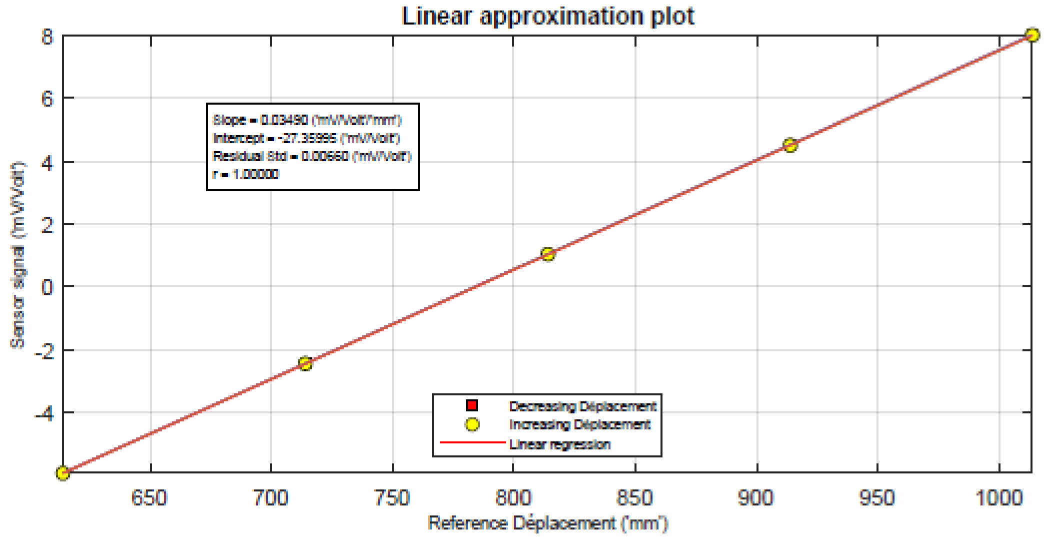
LHEEA CENTRALE NANTES
cnrs

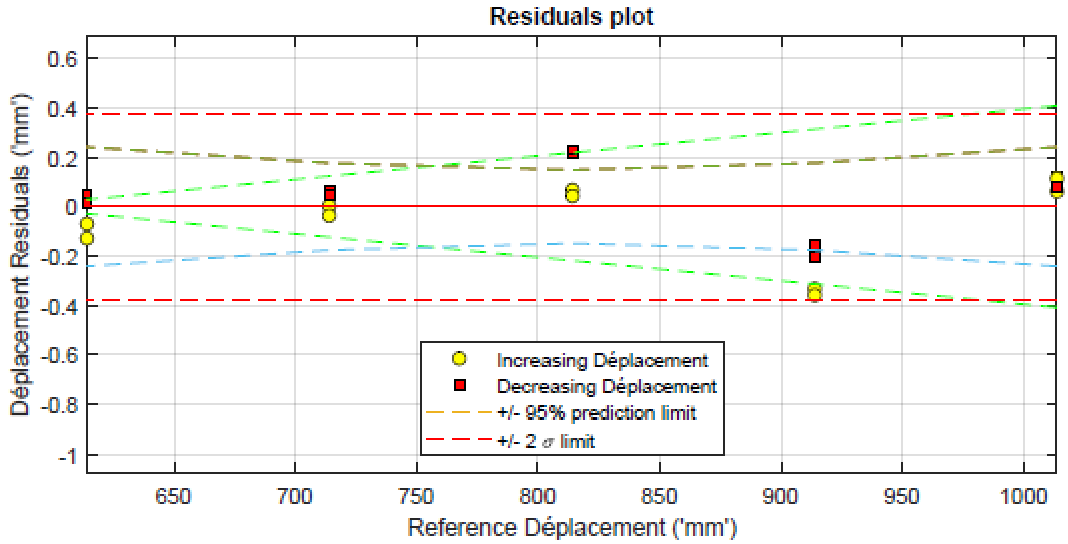
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'
Manufacturer: 'Laboratoire'
Sensor Name: 'WG6'
Sensor Reference: 'WG9'
Full Range:600 'mm'

Calibration reference standard:
'Banc Etal sonde à houle WDS1000'
Acquisition device: 'Quantum'
5 points (5 Sec @100Hz)
2 Cycle(s) (advance & return)





Sensitivity = 28.656 ('mm'/'mV/Volt')
Intercept = 784.017 ('mm')
Linearity = 0.09 (%FS)
Hysteresis = 0.04 (%FS)
Repetability = 0.01 (%FS)

Residual Std = 0.189 'mm'
Coverage factor = 2
Expanded uncertainty = 0.38 'mm'
Signal Stdev = 0.002 (%FS)

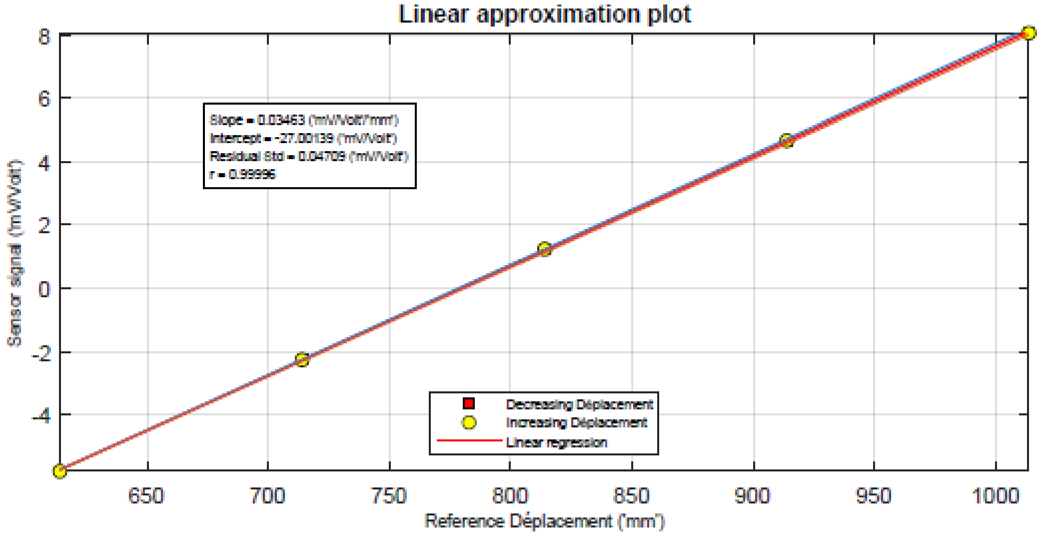
Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

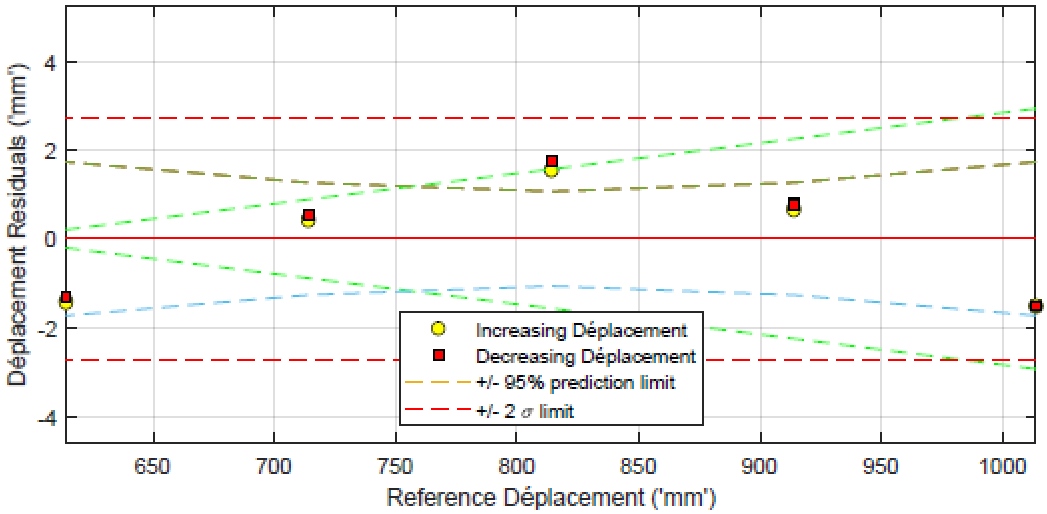
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'Laboratoire'	'Banc Etal sonde à houle WDS1000'
Sensor Name: 'WG7'	Acquisition device: 'Quantum'
Sensor Reference: 'WG14'	5 points (5 Sec @100Hz)
Full Range:600 'mm'	2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



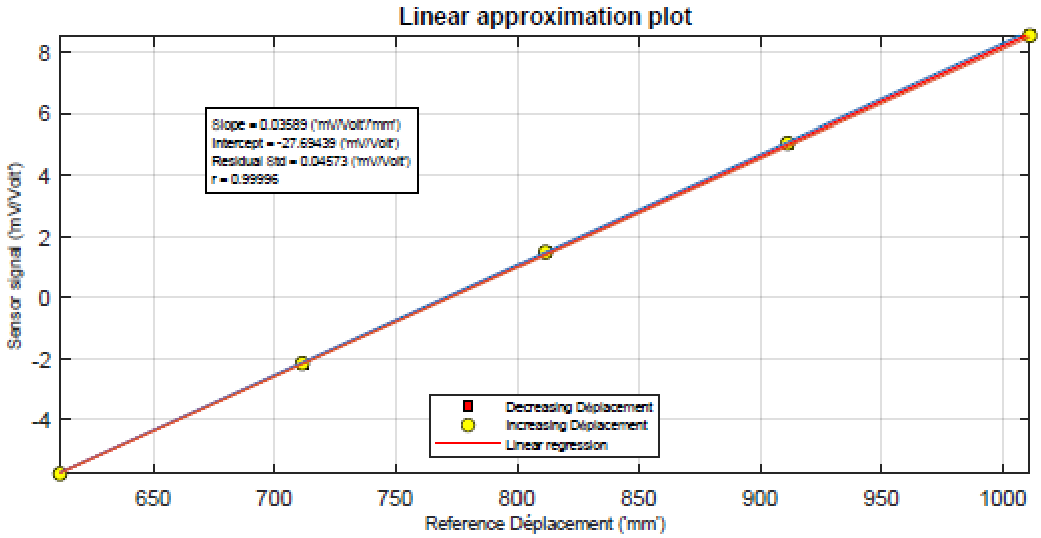
Sensitivity = 28.875 ('mm'/'mV/Volt')	Residual Std = 1.360 'mm'
Intercept = 779.657 ('mm')	Coverage factor = 2
Linearity = 0.44 (%FS)	Expanded uncertainty = 2.72 'mm'
Hysteresis = 0.04 (%FS)	Signal Stdev = 0.002 (%FS)
Repetability = 0.02 (%FS)	

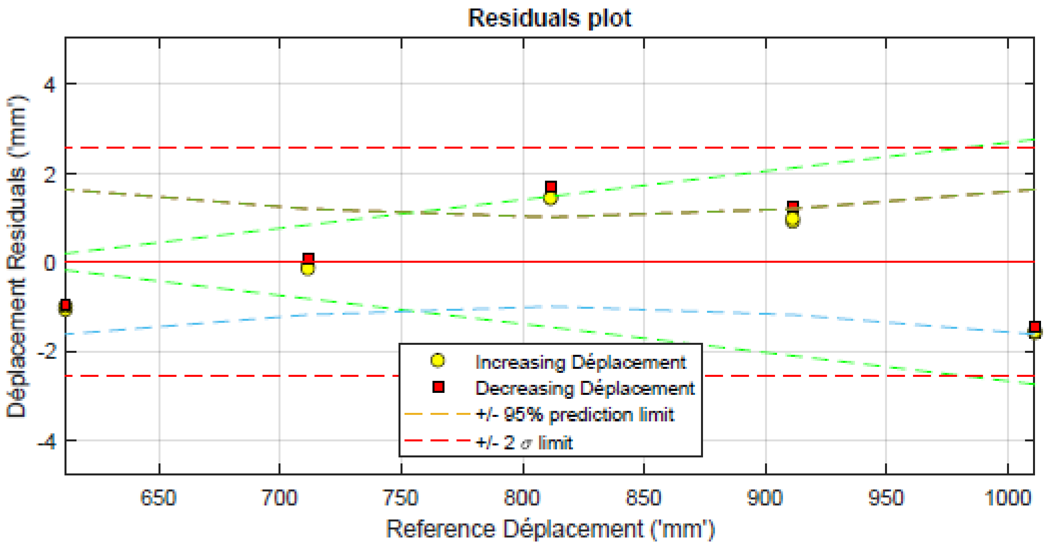
Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'Laboratoire'	'Banc Etal sonde à houle WDS1000'
Sensor Name: 'WG8'	Acquisition device: 'Quantum'
Sensor Reference: 'WG19'	5 points (5 Sec @100Hz)
Full Range:600 'mm'	2 Cycle(s) (advance & return)





Sensitivity = 27.865 ('mm'/'mV/Volt')	Residual Std = 1.274 'mm'
Intercept = 771.715 ('mm')	Coverage factor = 2
Linearity = 0.42 (%FS)	Expanded uncertainty = 2.55 'mm'
Hysteresis = 0.06 (%FS)	Signal Stdev = 0.002 (%FS)
Repetability = 0.03 (%FS)	

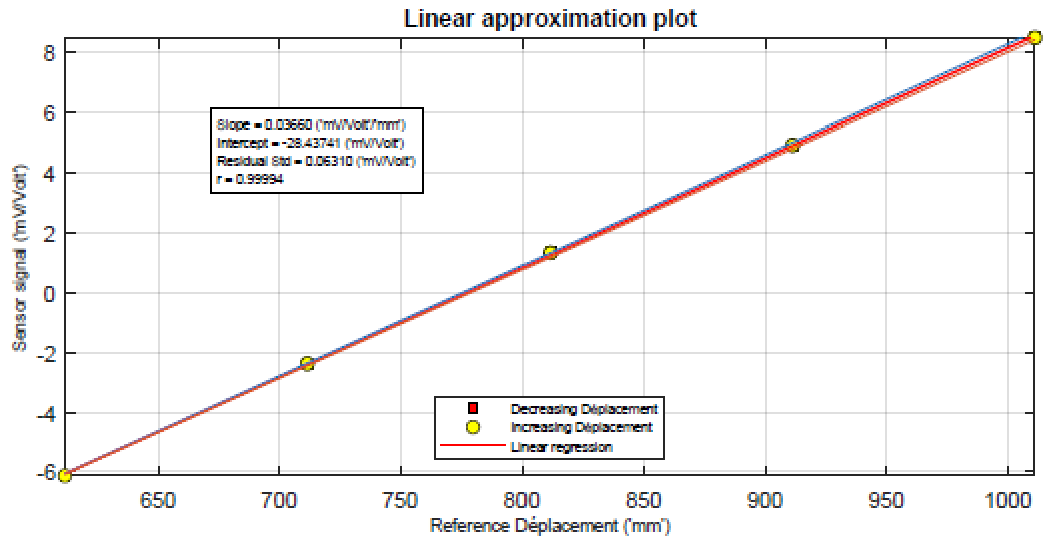
Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

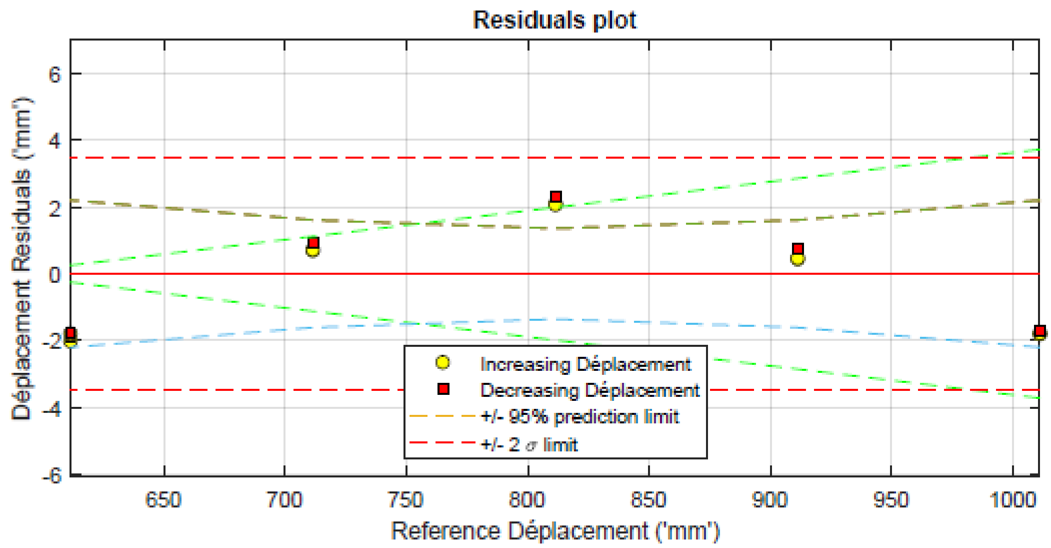
LHEEA CENTRALE NANTES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'Laboratoire'	'Banc Etal sonde à houle WDS1000'
Sensor Name: 'WG9'	Acquisition device: 'Quantum'
Sensor Reference: 'WG21'	5 points (5 Sec @100Hz)
Full Range:600 'mm'	2 Cycle(s) (advance & return)





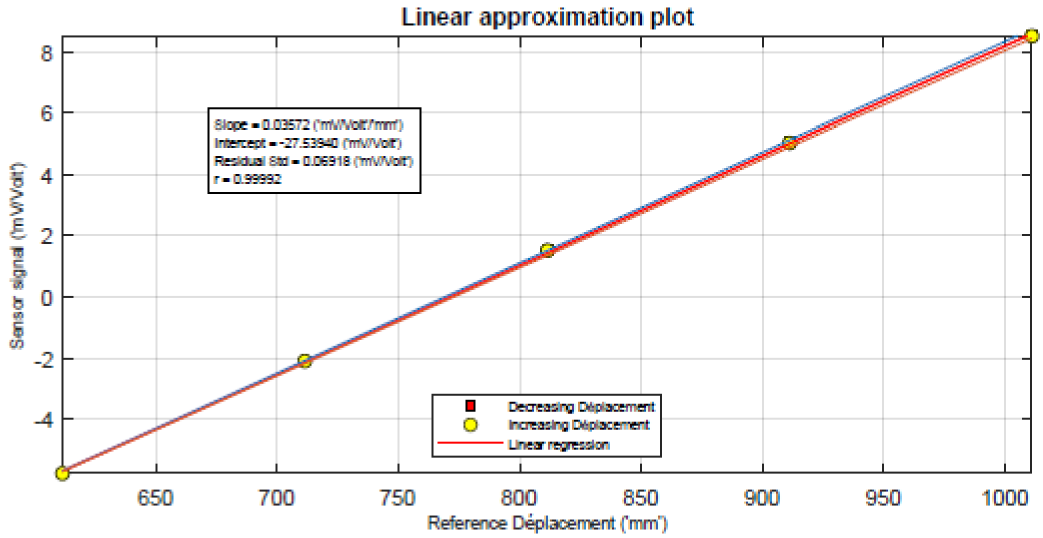
Sensitivity = 27.326 ('mm'/'mV/Volt')	Residual Std = 1.724 'mm'
Intercept = 777.083 ('mm')	Coverage factor = 2
Linearity = 0.59 (%FS)	Expanded uncertainty = 3.45 'mm'
Hysteresis = 0.07 (%FS)	Signal Stdev = 0.002 (%FS)
Repetability = 0.06 (%FS)	

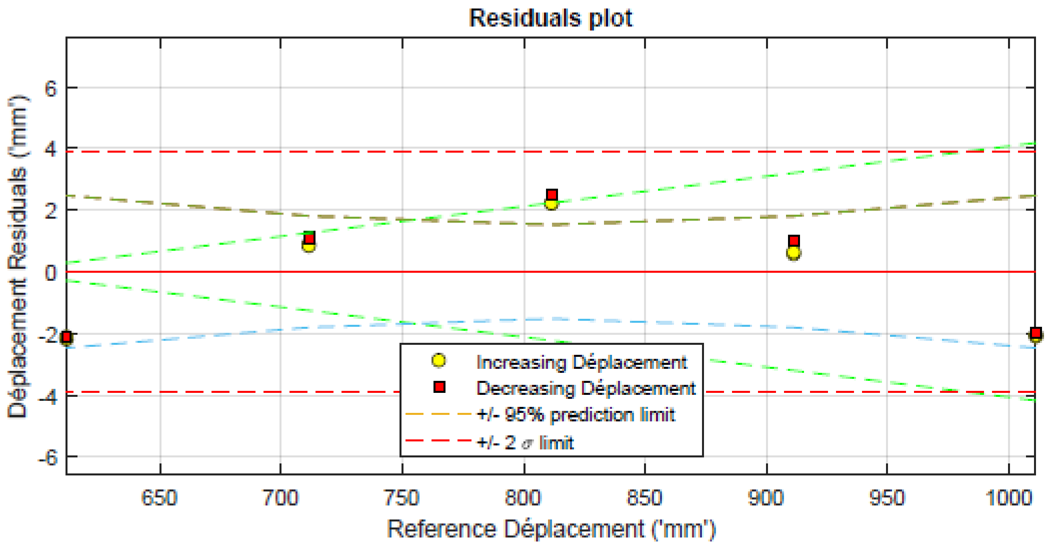
Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'Laboratoire'	'Banc Etal sonde à houle WDS1000'
Sensor Name: 'WG10'	Acquisition device: 'Quantum'
Sensor Reference: 'WG22'	5 points (5 Sec @100Hz)
Full Range:600 'mm'	2 Cycle(s) (advance & return)





Sensitivity = 27.993 ('mm'/'mV/Volt')	Residual Std = 1.936 'mm'
Intercept = 770.912 ('mm')	Coverage factor = 2
Linearity = 0.64 (%FS)	Expanded uncertainty = 3.87 'mm'
Hysteresis = 0.10 (%FS)	Signal Stdev = 0.002 (%FS)
Repetability = 0.02 (%FS)	

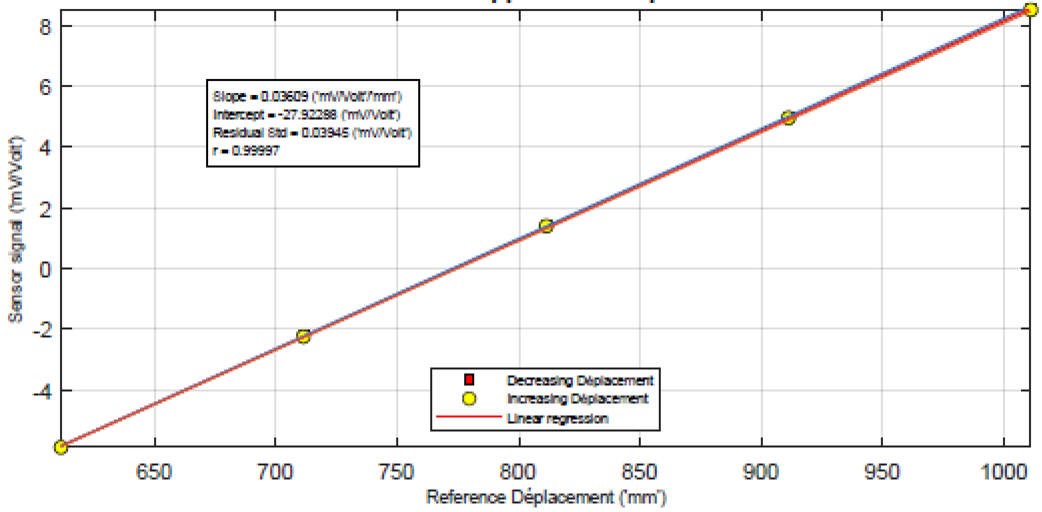
Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

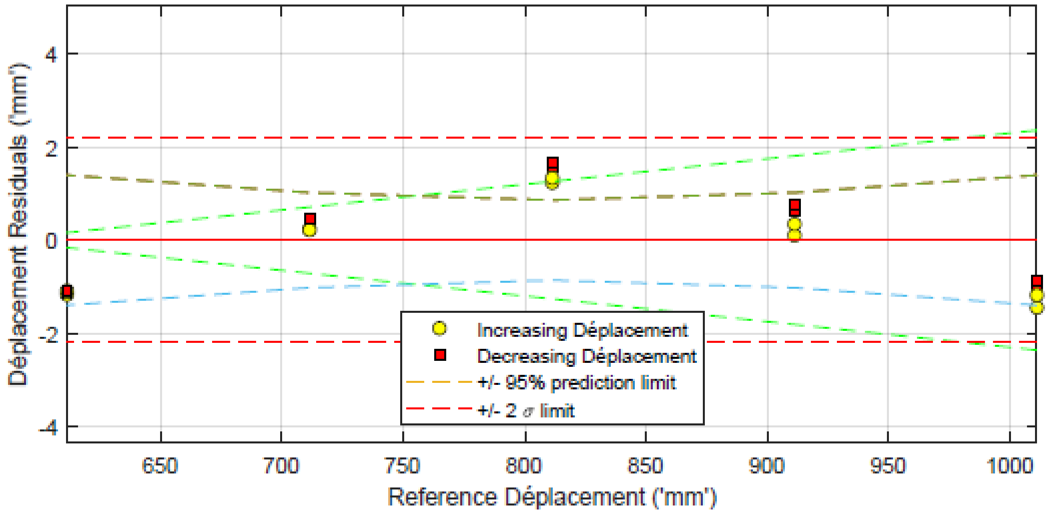
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D' Manufacturer: 'Laboratoire' Sensor Name: 'WG11' Sensor Reference: 'WG23' Full Range:600 'mm'	Calibration reference standard: 'Banc Etal sonde à houle WDS1000' Acquisition device: 'Quantum' 5 points (5 Sec @100Hz) 2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



Sensitivity = 27.709 ('mm'/'mV/Volt') Intercept = 773.713 ('mm') Linearity = 0.42 (%FS) Hysteresis = 0.12 (%FS) Repetability = 0.07 (%FS)	Residual Std = 1.093 'mm' Coverage factor = 2 Expanded uncertainty = 2.19 'mm' Signal Stdev = 0.002 (%FS)

Calibration by 'Bruno Pettinotti' - 21/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

LHEEA CENTRALE NANTES

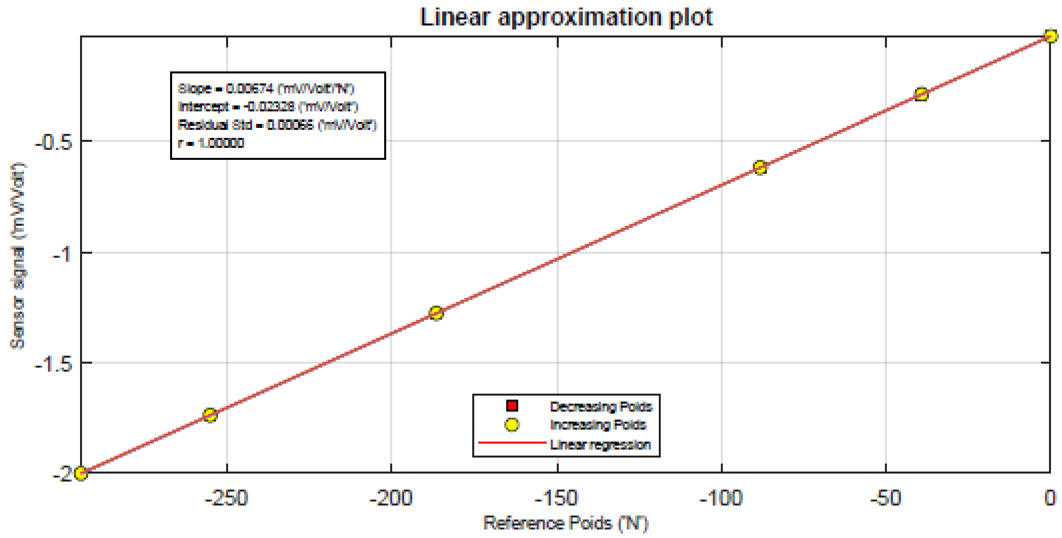
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

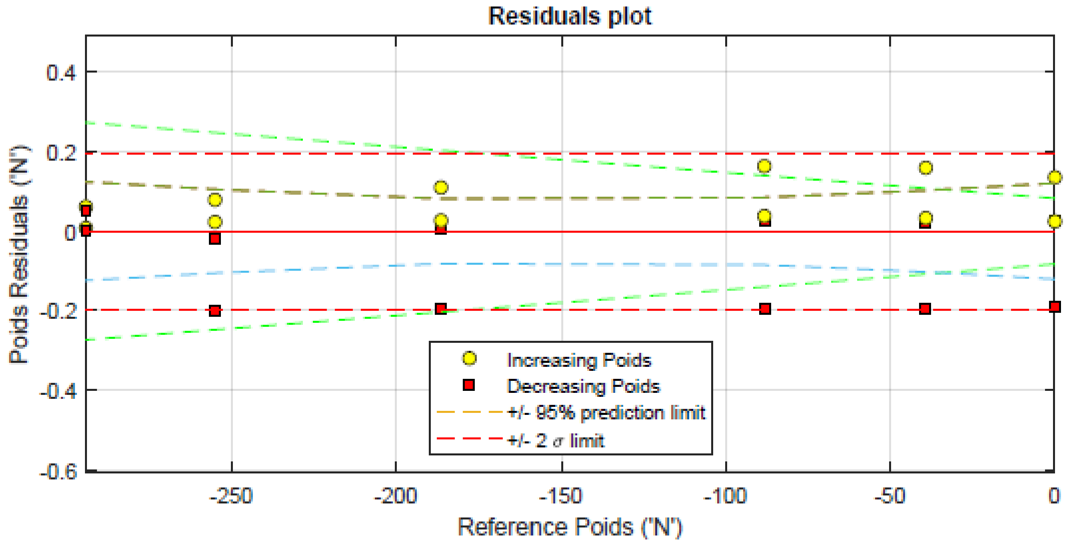
B. LOAD CELLS CALIBRATION RESULTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LIFTWEC' Manufacturer: 'HBM' Sensor Name: 'F1_neg' Sensor Reference: 'FOR251' Full Range:'(+/-)294.27' 'N'	Calibration reference standard: 'Standard masses M138601 class M1' Acquisition device: 'Quantum' 6 points (4 Sec @100Hz) 2 Cycle(s) (advance & return)





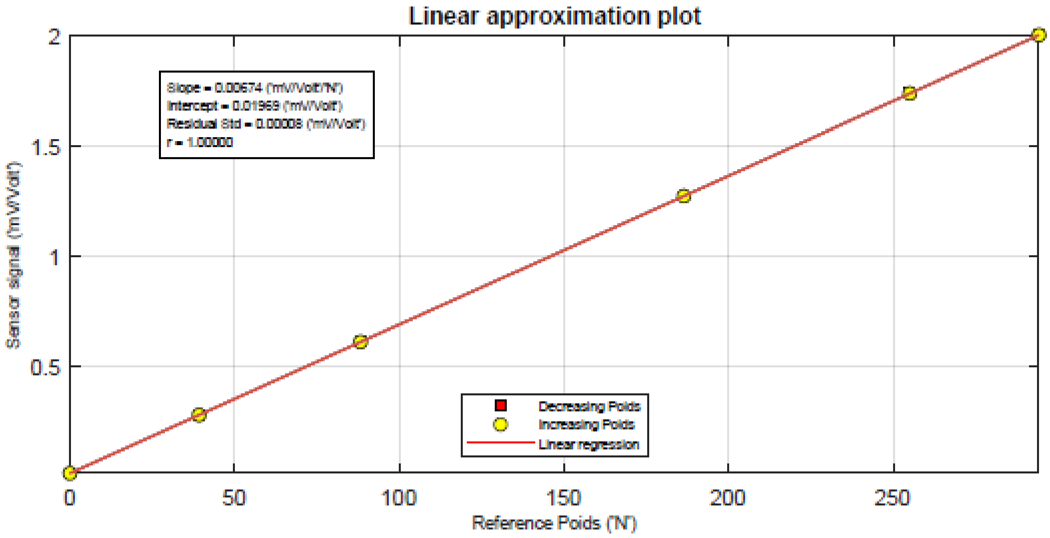
Sensitivity = 148.400 ('N'/'mV/Volt') Intercept = 3.455 ('N') Linearity = 0.04 (%FS) Hysteresis = 0.06 (%FS) Repetability = 0.07 (%FS)	Residual Std = 0.098 'N' Coverage factor = 2 Expanded uncertainty = 0.20 'N' Signal Stdev = 0.005 (%FS)

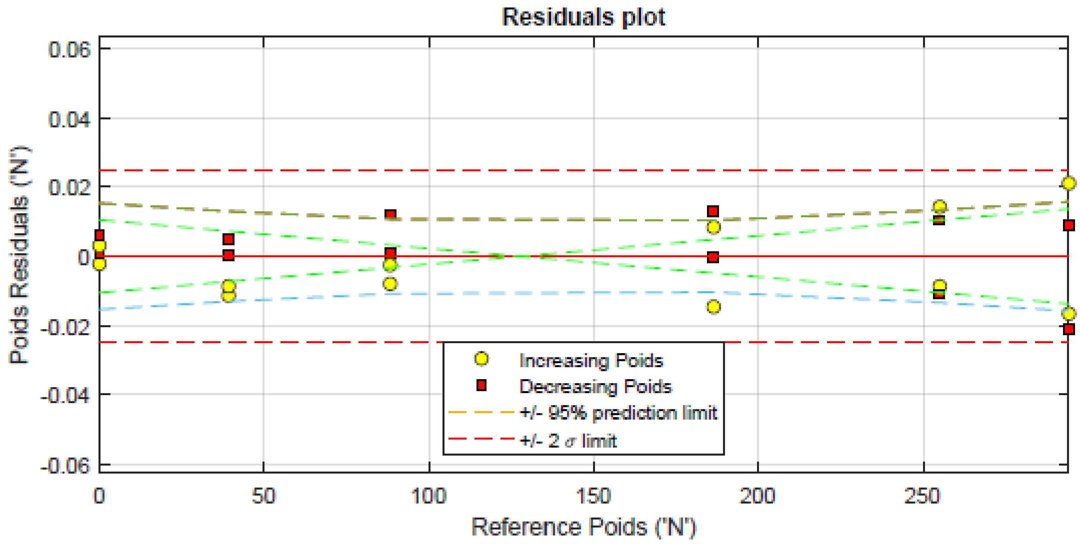
Calibration by 'Bruno Pettinotti' - 31/05/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LIFTWEC' Manufacturer: 'HBM' Sensor Name: 'F1_pos' Sensor Reference: 'FOR251' Full Range:'(+/-)294.27' 'N'	Calibration reference standard: 'Standard masses M138601 class M1' Acquisition device: 'Quantum' 6 points (4 Sec @100Hz) 2 Cycle(s) (advance & return)





Sensitivity = 148.421 ('N'/'mV/Volt') Intercept = -2.922 ('N') Linearity = 0.00 (%FS) Hysteresis = 0.00 (%FS) Repetability = 0.01 (%FS)	Residual Std = 0.013 'N' Coverage factor = 2 Expanded uncertainty = 0.03 'N' Signal Stdev = 0.005 (%FS)

Calibration by 'Bruno Pettinotti' - 31/05/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

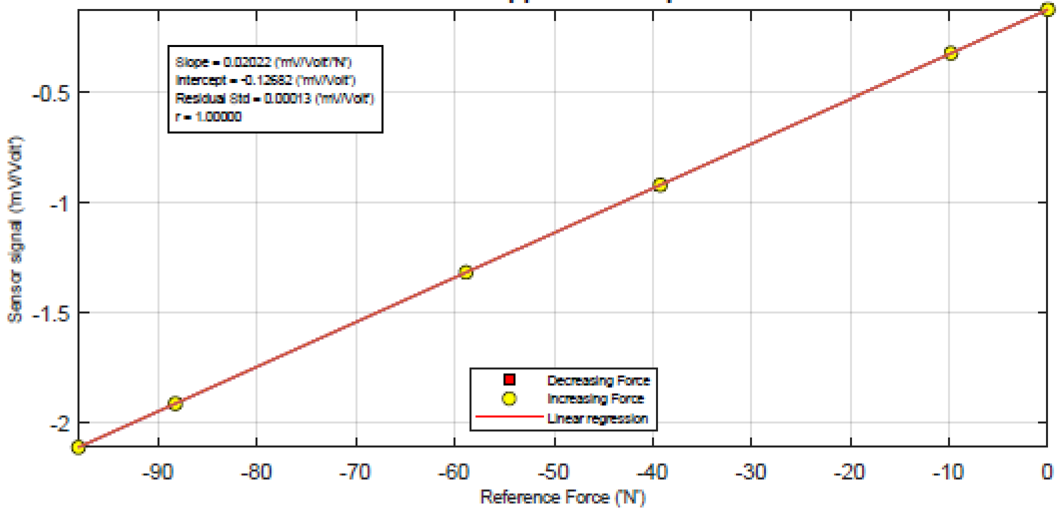
LHEEA CENTRALE NANTES
CNRS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

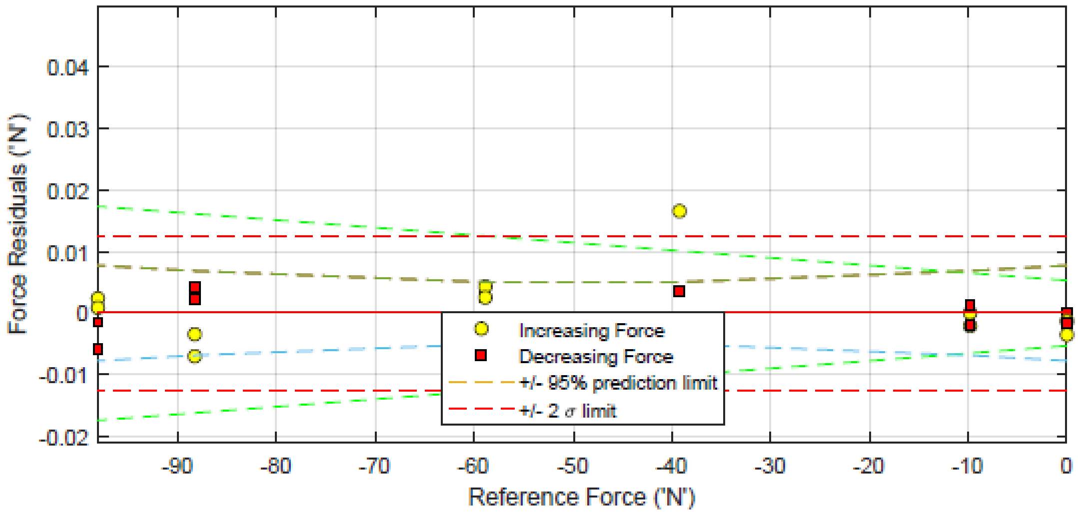
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'HBK'	'Standard masses M138601 class M1'
Sensor Name: 'F2_neg'	Acquisition device: 'Quantum'
Sensor Reference: 'FOR253'	6 points (4 Sec @100Hz)
Full Range:'(+/-)98.1' 'N'	2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



Sensitivity = 49.456 ('N'/'mV/Volt')	Residual Std = 0.006 'N'
Intercept = 6.272 ('N')	Coverage factor = 2
Linearity = 0.01 (%FS)	Expanded uncertainty = 0.01 'N'
Hysteresis = 0.01 (%FS)	Signal Stdev = 0.009 (%FS)
Repetability = 0.02 (%FS)	

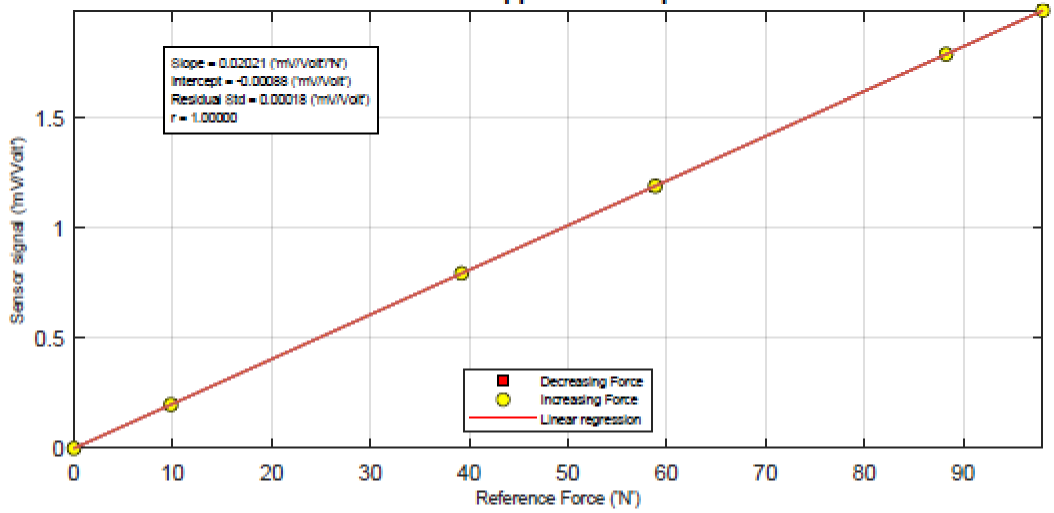
Calibration by 'Bruno Pettinotti' - 31/05/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

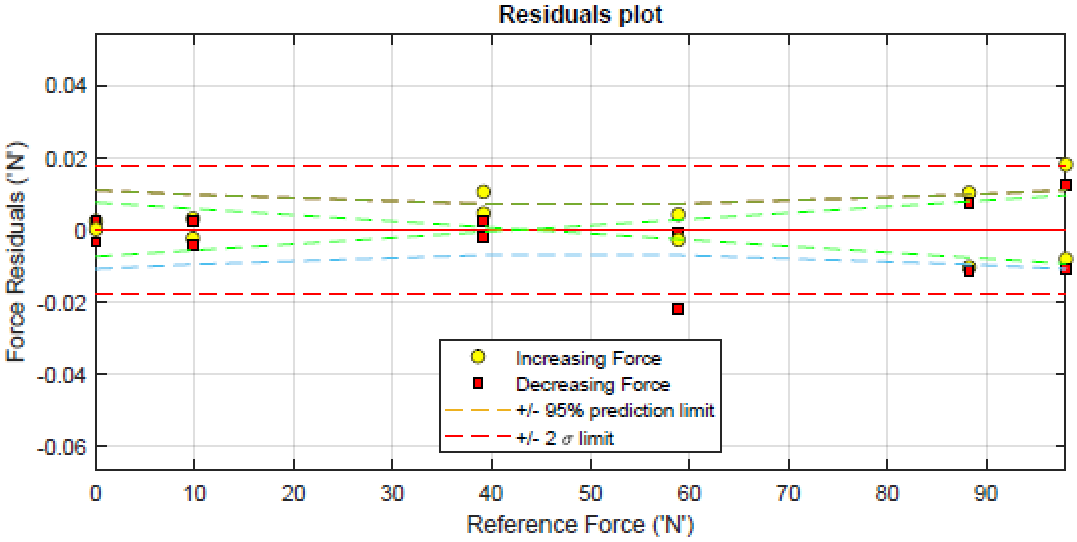
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D' Manufacturer: 'HBK' Sensor Name: 'F2_pos' Sensor Reference: 'FOR253' Full Range:'(+/-)98.1' 'N'	Calibration reference standard: 'Standard masses M138601 class M1' Acquisition device: 'Quantum' 6 points (4 Sec @100Hz) 2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



Sensitivity = 49.470 ('N/'mV/Volt') Intercept = 0.044 ('N') Linearity = 0.01 (%FS) Hysteresis = 0.01 (%FS) Repetability = 0.03 (%FS)	Residual Std = 0.009 'N' Coverage factor = 2 Expanded uncertainty = 0.02 'N' Signal Stdev = 0.011 (%FS)

Calibration by 'Bruno Pettinotti' - 31/05/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

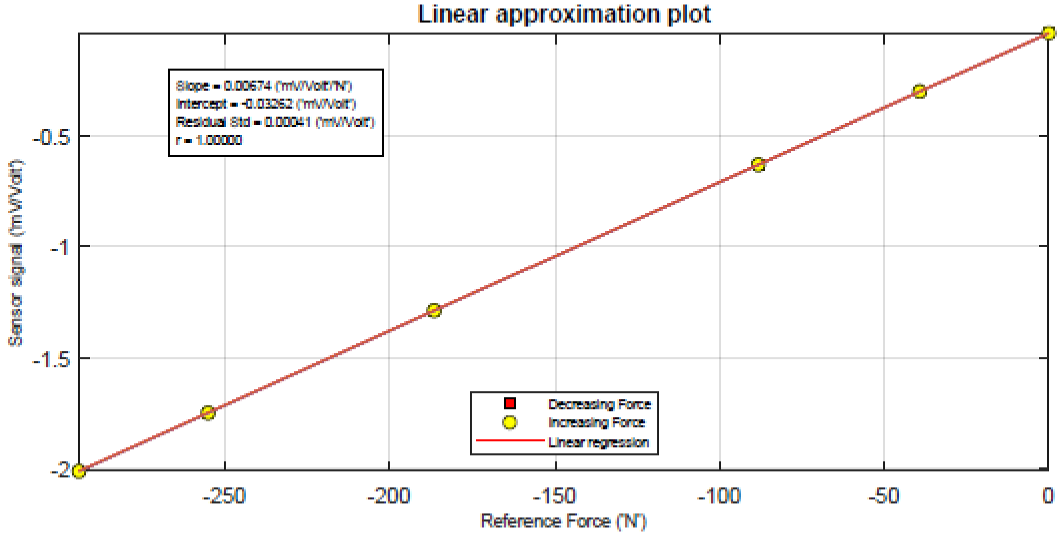
LHEEA CENTRALE NANTES

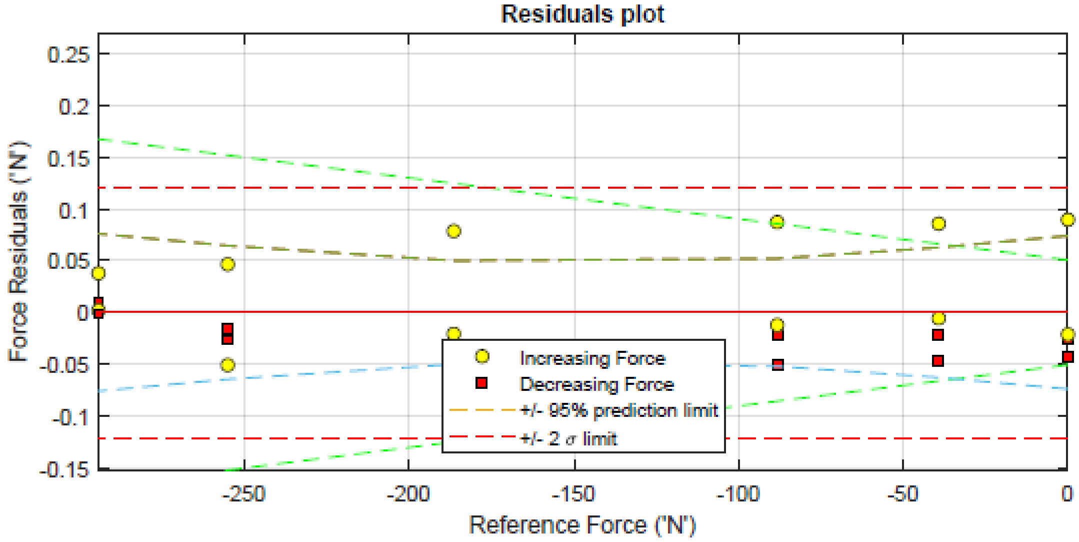
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'
Manufacturer: 'HBK'
Sensor Name: 'F3_neg'
Sensor Reference: 'FOR247'
Full Range:'(+/-)294.27' 'N'

Calibration reference standard:
'Standard masses M138601 class M1'
Acquisition device: 'Quantum'
6 points (4 Sec @100Hz)
2 Cycle(s) (advance & return)





Sensitivity = 148.385 ('N'/'mV/Volt')
Intercept = 4.840 ('N')
Linearity = 0.01 (%FS)
Hysteresis = 0.03 (%FS)
Repetability = 0.04 (%FS)

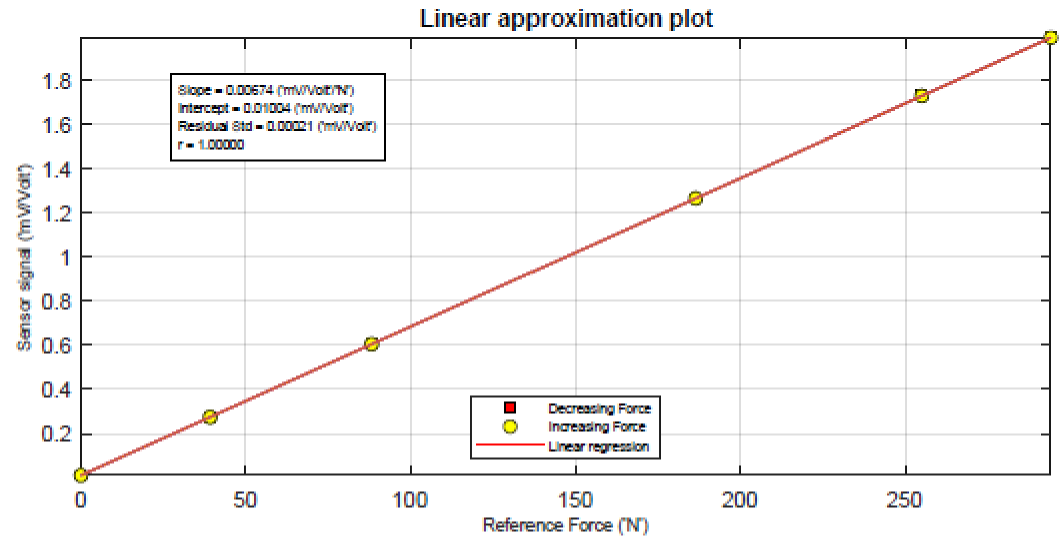
Residual Std = 0.060 'N'
Coverage factor = 2
Expanded uncertainty = 0.12 'N'
Signal Stdev = 0.006 (%FS)

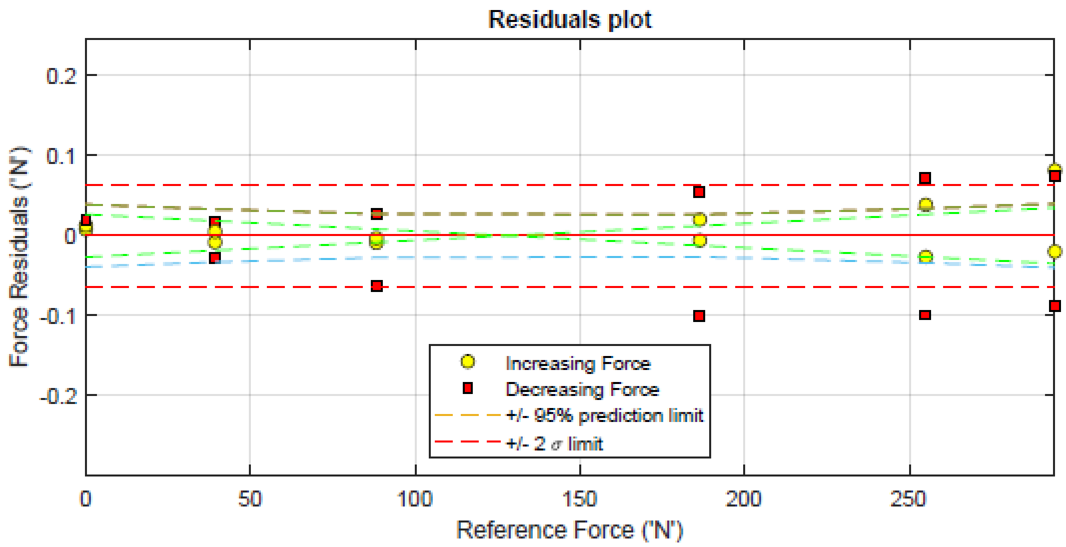
Calibration by 'Bruno Pettinotti' - 31/05/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'HBK'	'Standard masses M138601 class M1'
Sensor Name: 'F3_pos'	Acquisition device: 'Quantum'
Sensor Reference: 'FOR247'	6 points (4 Sec @100Hz)
Full Range:'(+/-)294.27' 'N'	2 Cycle(s) (advance & return)





Sensitivity = 148.376 ('N'/'mV/Volt')	Residual Std = 0.032 'N'
Intercept = -1.489 ('N')	Coverage factor = 2
Linearity = 0.01 (%FS)	Expanded uncertainty = 0.06 'N'
Hysteresis = 0.01 (%FS)	Signal Stdev = 0.007 (%FS)
Repetability = 0.06 (%FS)	

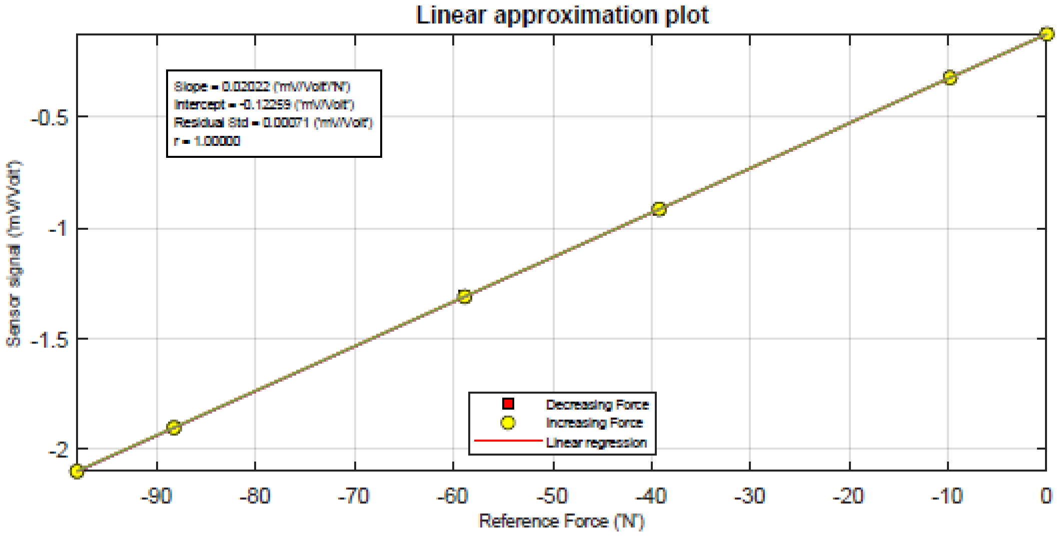
Calibration by 'Bruno Pettinotti' - 31/05/2021
Reference documents:

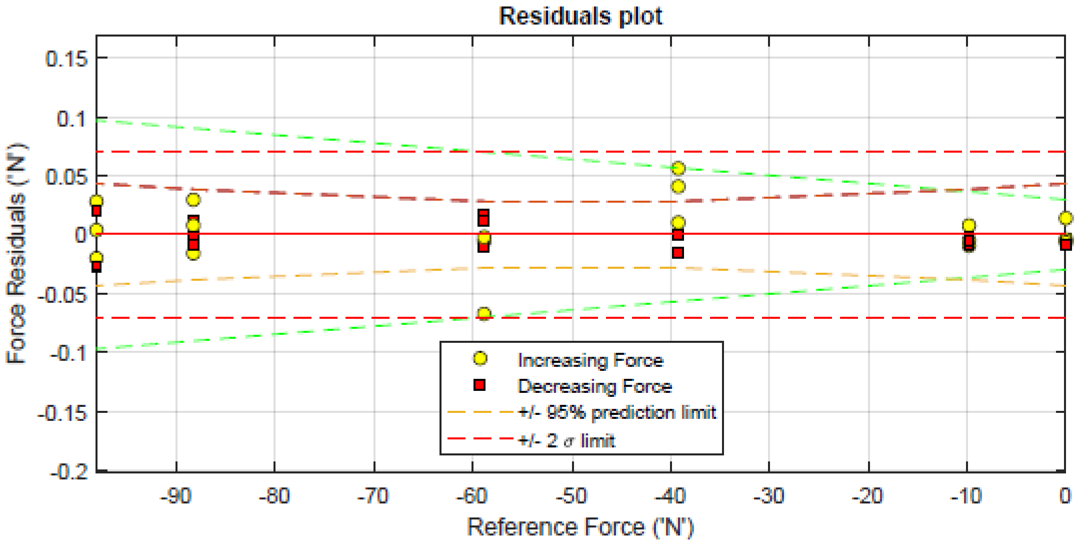
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D' Manufacturer: 'HBK' Sensor Name: 'F4_neg' Sensor Reference: 'FOR254' Full Range:'(+/-)98.1' 'N'	Calibration reference standard: 'Standard masses M138601 class M1' Acquisition device: 'Quantum' 6 points (4 Sec @100Hz) 3 Cycle(s) (advance & return)





Sensitivity = 49.465 ('N'/'mV/Volt') Intercept = 6.064 ('N') Linearity = 0.04 (%FS) Hysteresis = 0.04 (%FS) Repetability = 0.07 (%FS)	Residual Std = 0.035 'N' Coverage factor = 2 Expanded uncertainty = 0.07 'N' Signal Stdev = 0.005 (%FS)

Calibration by 'Bruno Pettinotti' - 15/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

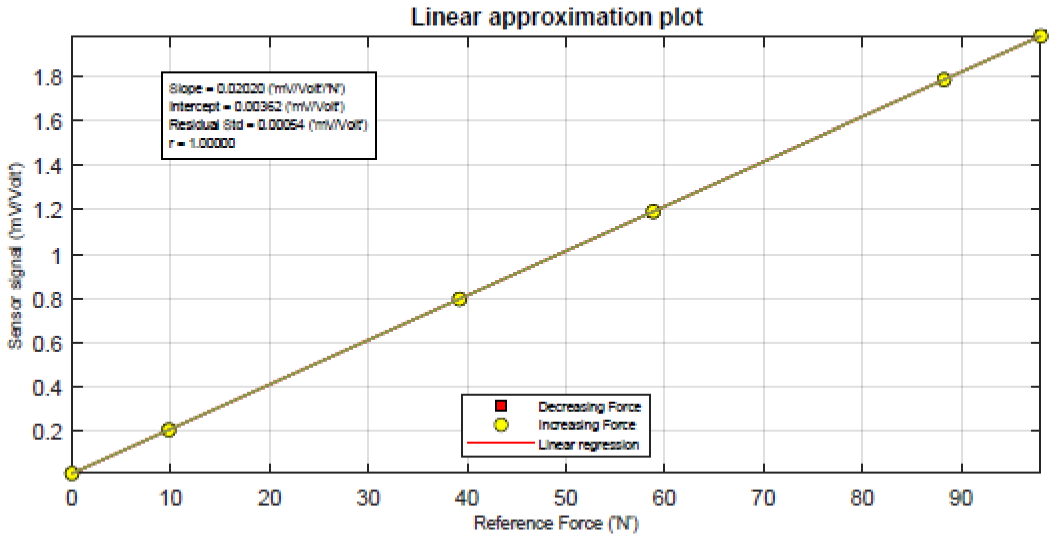
LHEEA CENTRALE NANTES

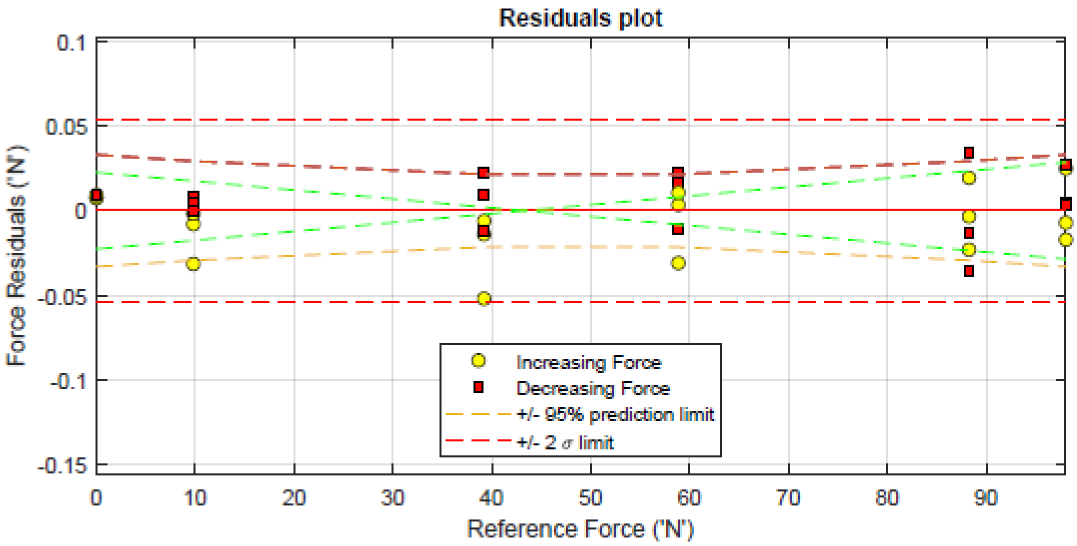
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'
Manufacturer: 'HBK'
Sensor Name: 'F4_pos'
Sensor Reference: 'FOR254'
Full Range:'(+/-)98.1' 'N'

Calibration reference standard:
'Standard masses M138601 class M1'
Acquisition device: 'Quantum'
6 points (4 Sec @100Hz)
3 Cycle(s) (advance & return)





Sensitivity = 49.496 ('N'/'mV/Volt')
Intercept = -0.179 ('N')
Linearity = 0.02 (%FS)
Hysteresis = 0.03 (%FS)
Repetability = 0.07 (%FS)

Residual Std = 0.027 'N'
Coverage factor = 2
Expanded uncertainty = 0.05 'N'
Signal Stdev = 0.006 (%FS)

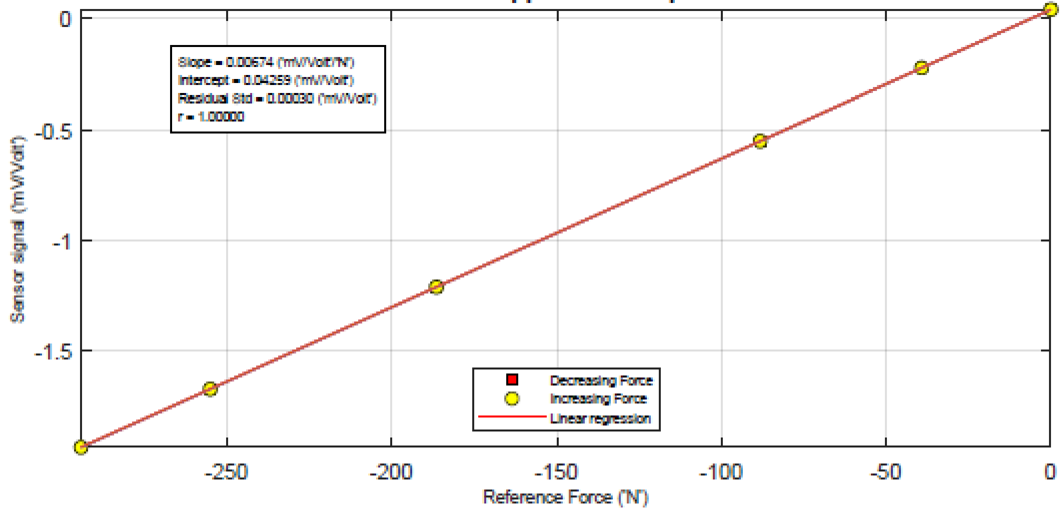
Calibration by 'Bruno Pettinotti' - 15/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

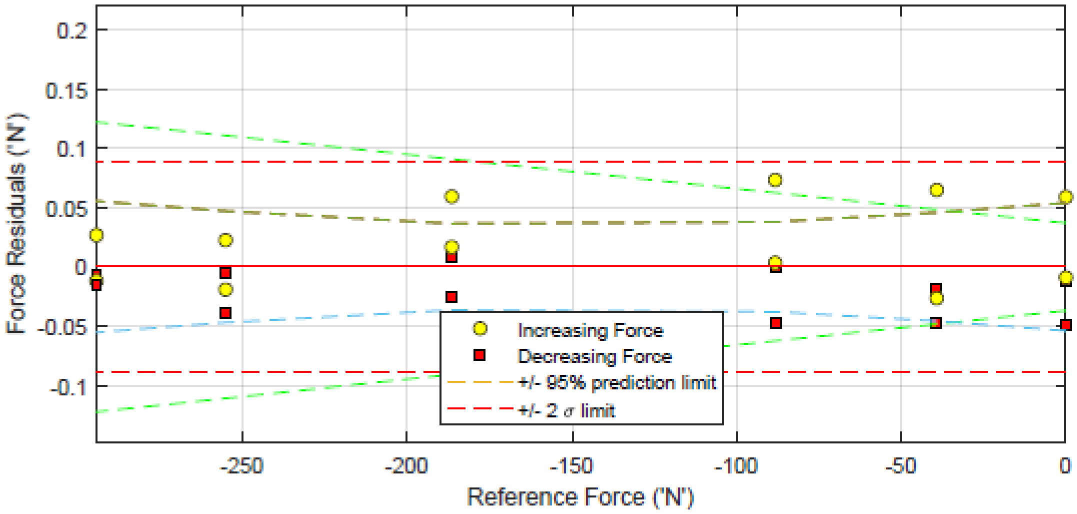
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'HBK'	'Standard masses M138601 class M1'
Sensor Name: 'F5_neg'	Acquisition device: 'Quantum'
Sensor Reference: 'FOR250'	6 points (4 Sec @100Hz)
Full Range:'(+/-)294.27' 'N'	2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



Sensitivity = 148.303 ('N'/'mV/Volt')	Residual Std = 0.044 'N'
Intercept = -6.316 ('N')	Coverage factor = 2
Linearity = 0.01 (%FS)	Expanded uncertainty = 0.09 'N'
Hysteresis = 0.02 (%FS)	Signal Stdev = 0.005 (%FS)
Repetability = 0.03 (%FS)	

Calibration by 'Bruno Pettinotti' - 31/05/2021

Reference documents:

[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.

[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

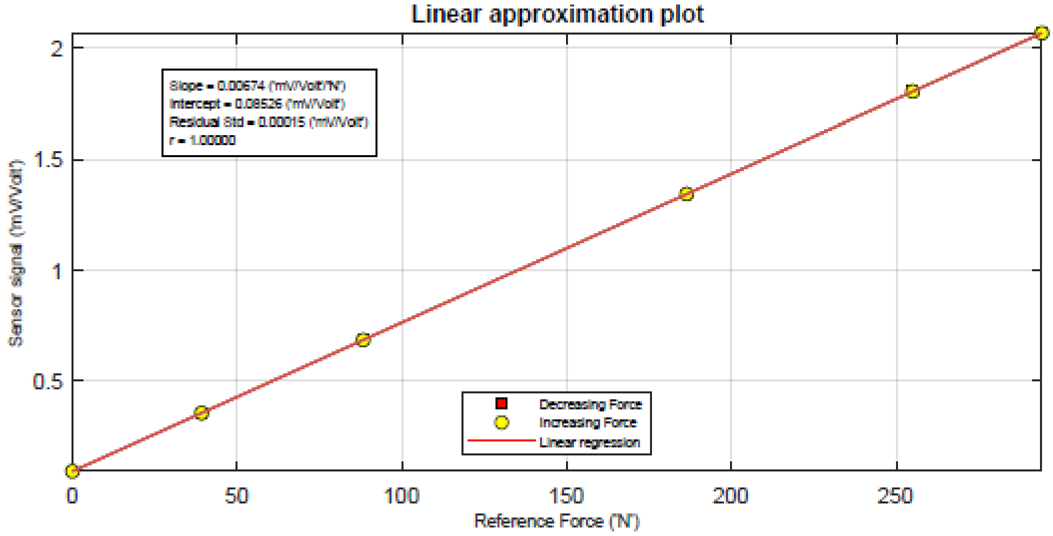
LHEEA CENTRALE NANTES
cnrs

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

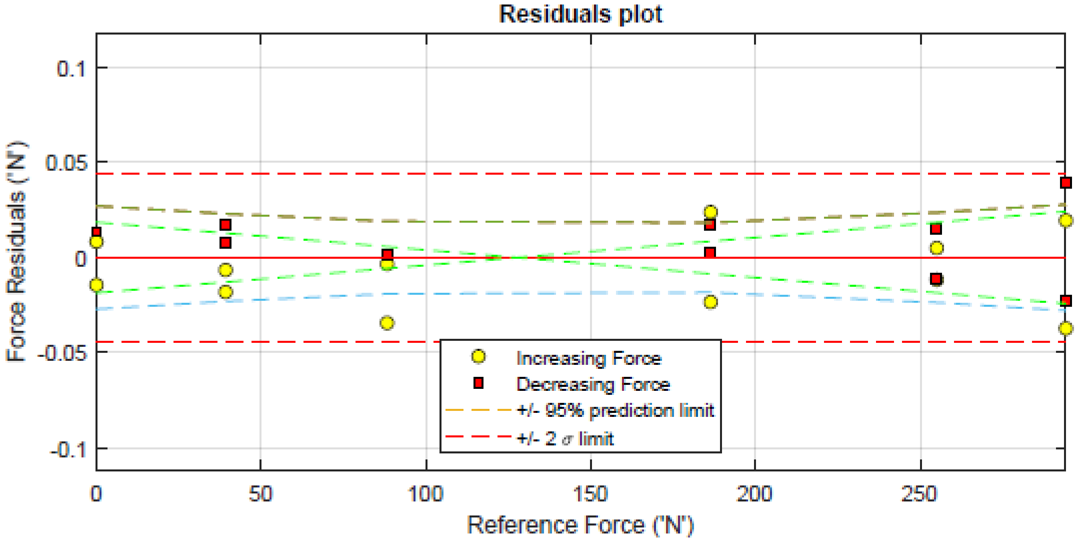
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'HBK'	'Standard masses M138601 class M1'
Sensor Name: 'F5_pos'	Acquisition device: 'Quantum'
Sensor Reference: 'FOR250'	6 points (4 Sec @100Hz)
Full Range:'(+/-)294.27' 'N'	2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



Sensitivity = 148.343 ('N'/'mV/Volt')	Residual Std = 0.022 'N'
Intercept = -12.648 ('N')	Coverage factor = 2
Linearity = 0.01 (%FS)	Expanded uncertainty = 0.04 'N'
Hysteresis = 0.01 (%FS)	Signal Stdev = 0.006 (%FS)
Repetability = 0.02 (%FS)	

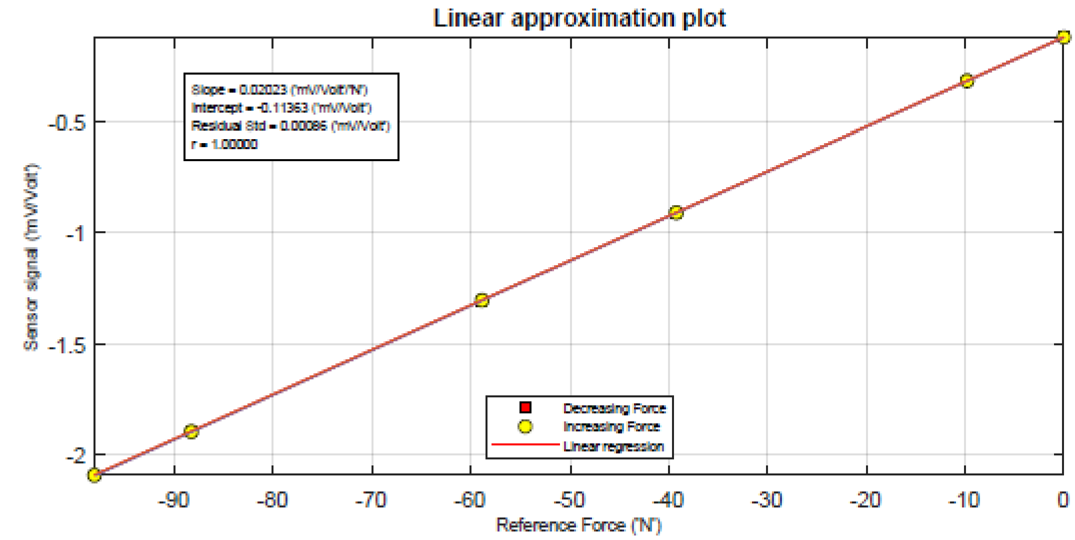
Calibration by 'Bruno Pettinotti' - 01/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

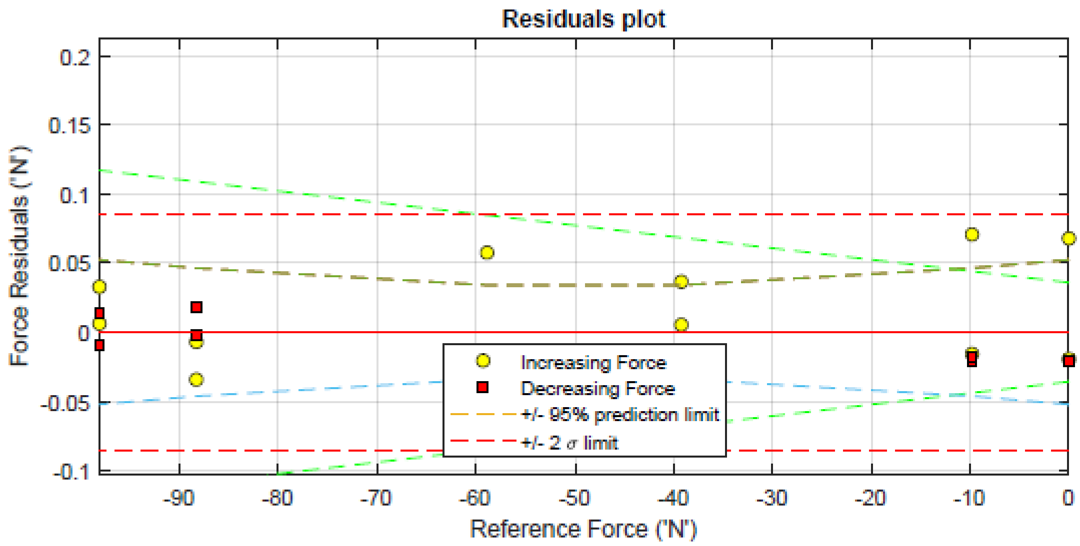
LHEEA CENTRALE NANTES

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'HBK'	'Standard masses M138601 class M1'
Sensor Name: 'F6_neg'	Acquisition device: 'Quantum'
Sensor Reference: 'FOR252'	6 points (4 Sec @100Hz)
Full Range:'(+/-)98.1' 'N'	2 Cycle(s) (advance & return)





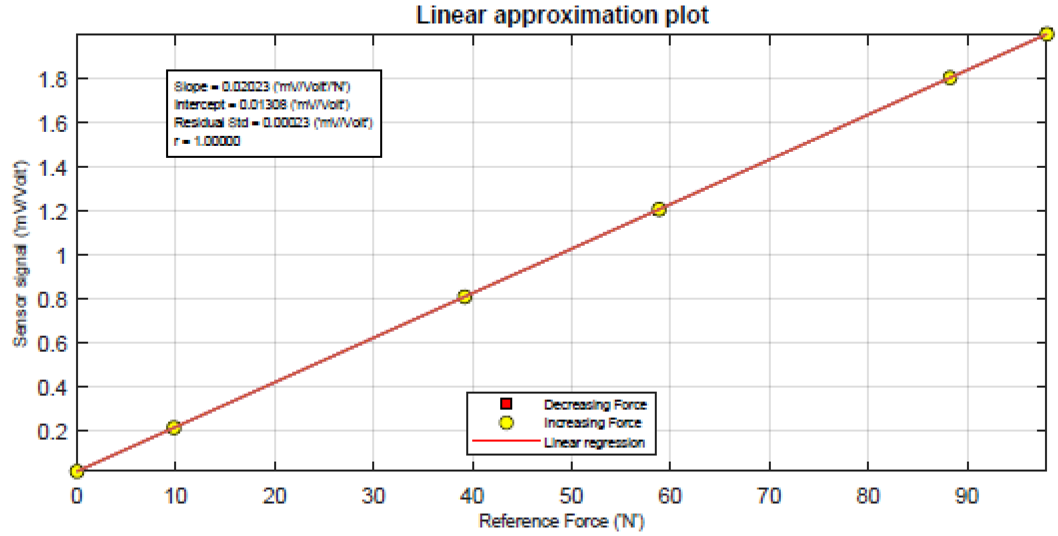
Sensitivity = 49.426 ('N'/'mV/Volt')	Residual Std = 0.042 'N'
Intercept = 5.616 ('N')	Coverage factor = 2
Linearity = 0.03 (%FS)	Expanded uncertainty = 0.08 'N'
Hysteresis = 0.05 (%FS)	Signal Stdev = 0.008 (%FS)
Repetability = 0.09 (%FS)	

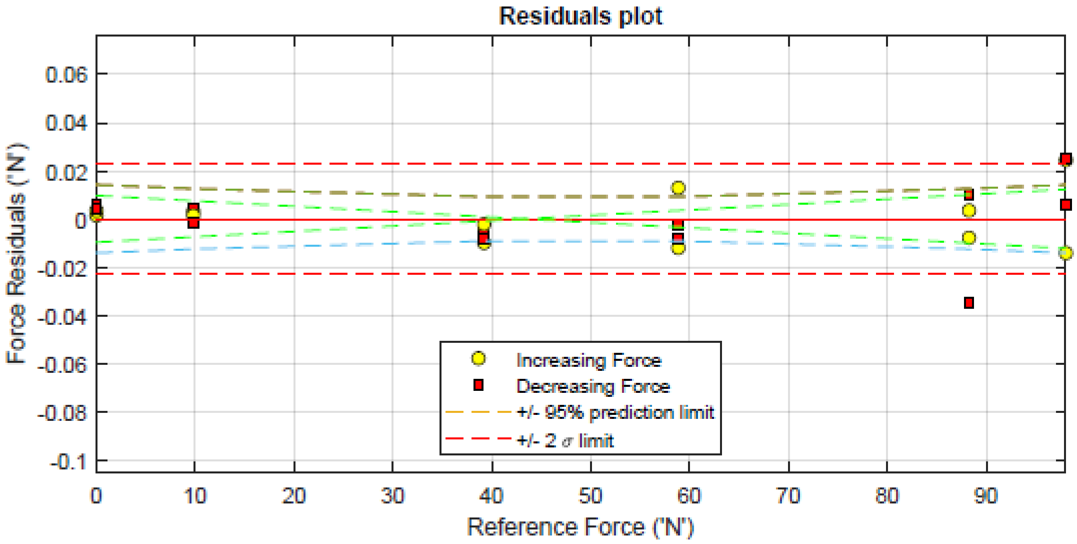
Calibration by 'Bruno Pettinotti' - 01/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D' Manufacturer: 'HBK' Sensor Name: 'F6_pos' Sensor Reference: 'FOR252' Full Range:'(+/-)98.1' 'N'	Calibration reference standard: 'Standard masses M138601 class M1' Acquisition device: 'Quantum' 6 points (4 Sec @100Hz) 2 Cycle(s) (advance & return)





Sensitivity = 49.437 ('N'/'mV/Volt') Intercept = -0.647 ('N') Linearity = 0.02 (%FS) Hysteresis = 0.01 (%FS) Repetability = 0.05 (%FS)	Residual Std = 0.011 'N' Coverage factor = 2 Expanded uncertainty = 0.02 'N' Signal Stdev = 0.007 (%FS)

Calibration by 'Bruno Pettinotti' - 01/06/2021

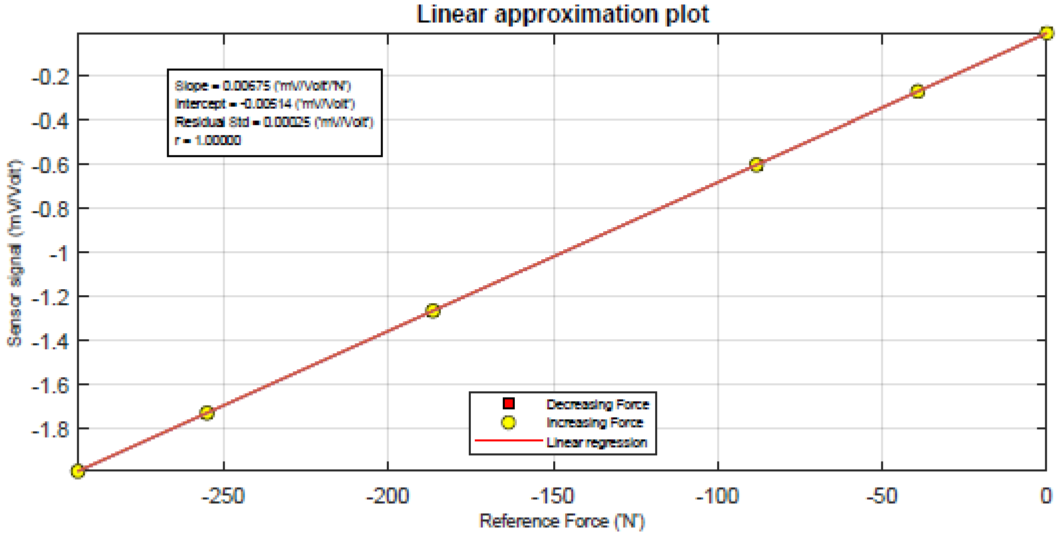
Reference documents:

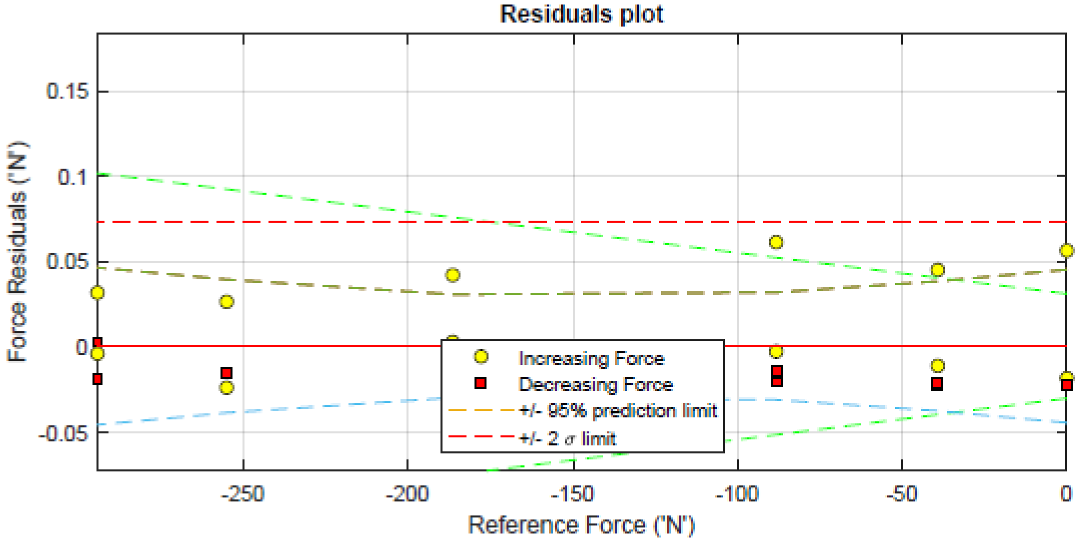
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'	Calibration reference standard:
Manufacturer: 'HBK'	'Standard masses M138601 class M1'
Sensor Name: 'F7_neg'	Acquisition device: 'Quantum'
Sensor Reference: 'FOR249'	6 points (4 Sec @100Hz)
Full Range:'(+/-)294.27' 'N'	2 Cycle(s) (advance & return)





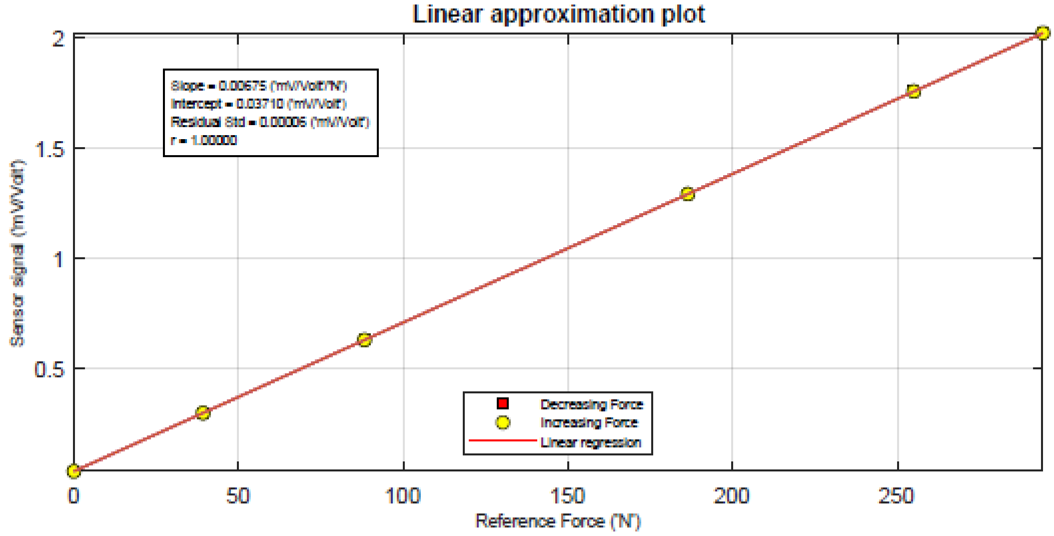
Sensitivity = 148.245 ('N'/'mV/Volt')	Residual Std = 0.037 'N'
Intercept = 0.762 ('N')	Coverage factor = 2
Linearity = 0.01 (%FS)	Expanded uncertainty = 0.07 'N'
Hysteresis = 0.02 (%FS)	Signal Stdev = 0.005 (%FS)
Repetability = 0.03 (%FS)	

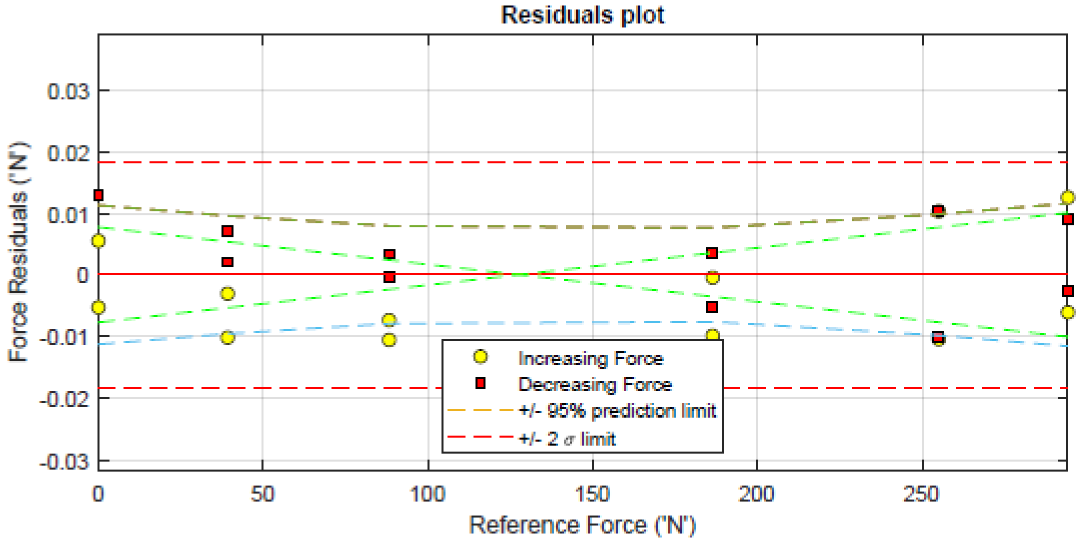
Calibration by 'Bruno Pettinotti' - 01/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D' Manufacturer: 'HBK' Sensor Name: 'F7_pos' Sensor Reference: 'FOR249' Full Range:'(+/-)294.27' 'N'	Calibration reference standard: 'Standard masses M138601 class M1' Acquisition device: 'Quantum' 6 points (4 Sec @100Hz) 2 Cycle(s) (advance & return)





Sensitivity = 148.217 ('N'/'mV/Volt') Intercept = -5.499 ('N') Linearity = 0.00 (%FS) Hysteresis = 0.00 (%FS) Repetability = 0.01 (%FS)	Residual Std = 0.009 'N' Coverage factor = 2 Expanded uncertainty = 0.02 'N' Signal Stdev = 0.004 (%FS)

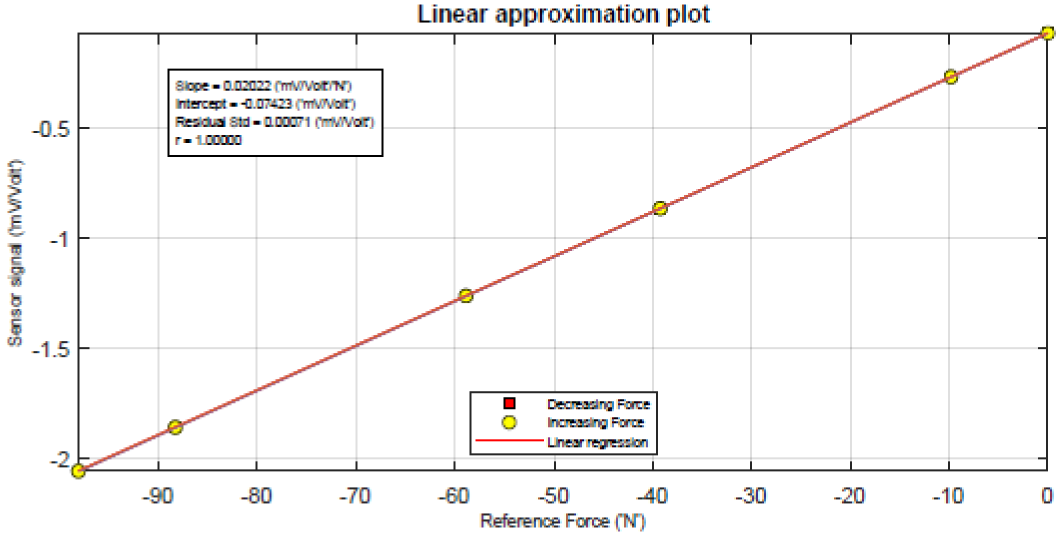
Calibration by 'Bruno Pettinotti' - 01/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

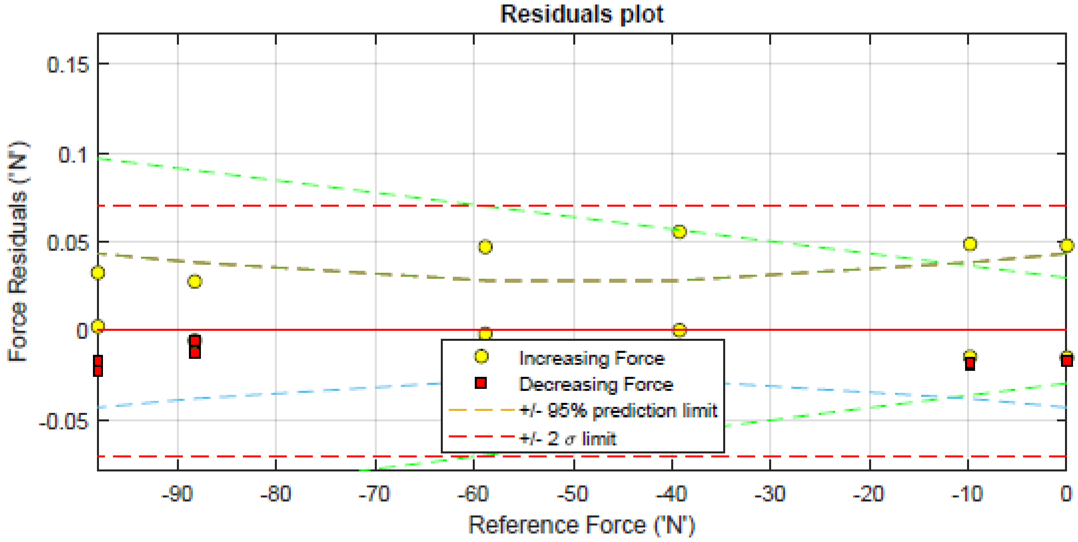
STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D' Manufacturer: 'HBK' Sensor Name: 'F8_neg' Sensor Reference: 'FOR255' Full Range:'(+/-)98.1' 'N'	Calibration reference standard: 'Standard masses M138601 class M1' Acquisition device: 'Quantum' 6 points (4 Sec @100Hz) 2 Cycle(s) (advance & return)

Linear approximation plot



Residuals plot



Sensitivity = 49.446 ('N'/'mV/Volt') Intercept = 3.671 ('N') Linearity = 0.03 (%FS) Hysteresis = 0.05 (%FS) Repetability = 0.06 (%FS)	Residual Std = 0.035 'N' Coverage factor = 2 Expanded uncertainty = 0.07 'N' Signal Stdev = 0.006 (%FS)

Calibration by 'Bruno Pettinotti' - 01/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

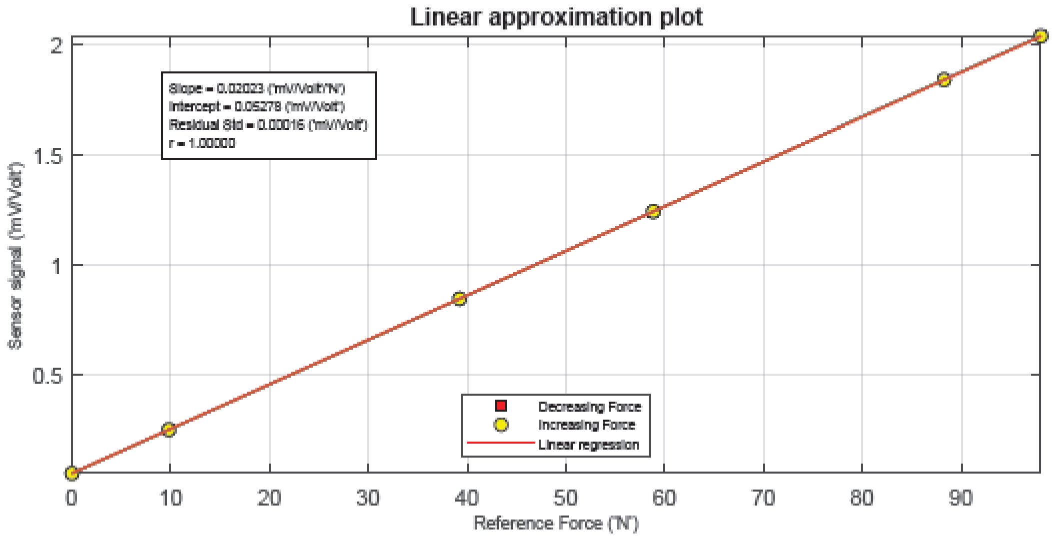
LHEEA CENTRALE NANTES

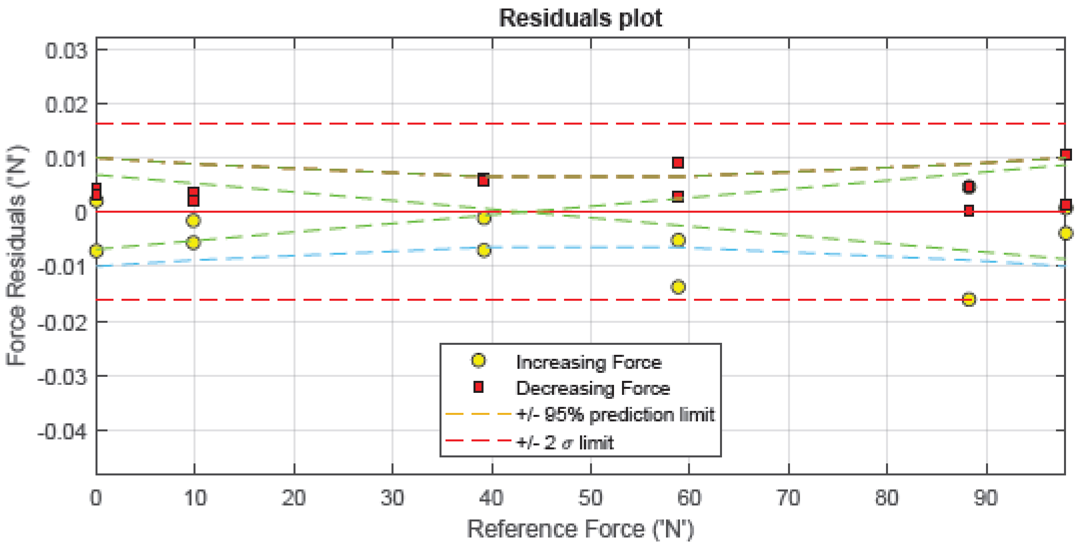
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

STATIC CALIBRATION REPORT

Project name: 'LiftWEC_2D'
Manufacturer: 'HBK'
Sensor Name: 'F8_pos'
Sensor Reference: 'FOR255'
Full Range:'(+/-)98.1' 'N'

Calibration reference standard:
'Standard masses M138601 class M1'
Acquisition device: 'Quantum'
6 points (4 Sec @100Hz)
2 Cycle(s) (advance & return)





Sensitivity = 49.435 ('N'/'mV/Volt')
Intercept = -2.609 ('N')
Linearity = 0.01 (%FS)
Hysteresis = 0.02 (%FS)
Repetability = 0.02 (%FS)

Residual Std = 0.008 'N'
Coverage factor = 2
Expanded uncertainty = 0.02 'N'
Signal Stdev = 0.007 (%FS)

Calibration by 'Bruno Pettinotti' - 01/06/2021
Reference documents:
[1] ITTC (2002) Procedures and Guidelines - 7.6-02-09 – Calibration of load cells.
[2] ITTC (2008) Procedures and Guidelines - 7.5-01-03-01 – Uncertainty analysis.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.

C. Torque meter factory certificate

ETH messtechnik gmbh

hagstrasse 10
D-74417 gschwend
telephon +49(0)7972.9310-0
telefax +49(0)7972.9310-50
http://www.eth-messtechnik.de
info@eth-messtechnik.de

Werkszertifikat

(Factory-Certificate)

Drehmomentsensor Typ DRBK-100
(Torque Transducer Type DRBK-100)

Seriennummer: (Serial Number) **809131601**

Nennmoment: (Nominal Torque)

☐ 0,5Nm	☐ 5Nm	☐ 50Nm	☐ 500Nm
☐ 1Nm	☐ 10Nm	☒ 100Nm	☐ 1000Nm
☐ 2Nm	☐ 20Nm	☐ 200Nm	

Option Drehzahl: (option speed) ☐ **Ja**

Max. zulässige Abweichung: (Max. Tolerance of Measurement) **≤0,5%**

Ergebnis der Drehmomentprüfung: (Result of torque test) **uneingeschränkt einsetzbar** (for use without restriction)

Ergebnis der Sichtprüfung: (Result of visual inspection) **ok**

Der Aufnehmer erfüllt die im Datenblatt angegebenen Spezifikationen.
(The Trancducer meets the specifications mentioned in the data-sheet)

Datum: (Date) 04.09.2019

Prüfer: (Examiner) Andreas Frost

Unterschrift: (Signature) A. Frost

Wir empfehlen eine Re-Kalibrierung 24 Monate nach Kalibrierdatum diese Produktes.
(24 months after date of calibration a re-calibration of this sensor is recommended)

Alle zur Kalibrierung verwendeten Geräte sind rückführbar auf nationale Normale, Normalmesseinrichtungen- und verfahren zur Darstellung der physikalischen Einheiten in Übereinstimmung mit dem internationalen Einheitensystem (SI)
(All Devices used for calibration can be tracked back to national standards, physical units comply with the international system of units, SI)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 851885. This output reflects the views only of the author(s), and the European Union cannot be held responsible for any use which may be made of the information contained therein.