LRD Tank Test - Summary Results

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Dublin Offshore

1 Introduction

Dublin Offshore have developed a subsea mooring component, the Load Reduction Device (LRD), which provides controlled mooring compliance of the platform and allows for significant reduction in design driving peak loads. Floating Offshore Wind (FOW) Mooring systems typically comprise mooring lines, anchors, and connectors. The cost of each of these components is directly related to the loading on the floating platform, resisted by the mooring line in tension. As load increases, the required capacity of the mooring system increases and cost increases. The provision of compliance, and reduction of mooring loads, allows for step-changes in the specification and cost of the FOW mooring, and significant reduction in the Levelised Cost of Energy (LCOE) of the system.

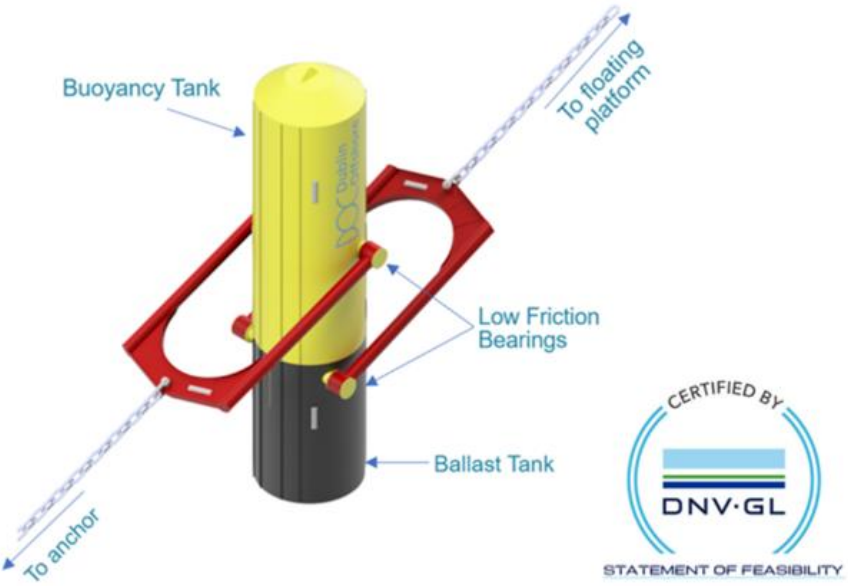


Figure 1 - Load Reduction Device (LRD)

Design loads for moorings are driven by extreme events, such as a 1 in 50 year maximum wave height, and far exceed typical operating loads. Traditional moorings are relatively inflexible; catenary and semi-taut moorings increase in stiffness as load is applied, resulting in snatch loads in extreme conditions such as demonstrated in the baseline test cases. A compliant mooring system allows the floating platform to move in response to large waves, instead of the current practice of resisting the full force of the sea. Dublin Offshore's LRD delivers a non-linear load versus extension response, allowing the platform to move in a compliant manner in response to large waves, and can significantly reduce the cost and risk to the mooring system.

The work described in this summary report is the result of ongoing development of the LRD at the deep Ocean Basin in the Lír National Ocean Test Facility (NOTF). This testing campaign focussed on challenging and aggressive sites with known mooring challenges. Videos from the testing can be viewed via the Dublin Offshore YouTube channel.

2 Test Description

The test programme was designed to replicate proposed floating wind site conditions off the west coast of Ireland, at 1:60 scale, for a 15MW semi-sub floating platform. In this testing, the MaRINET2 V3 FOW semi-sub platform was used. The platform is 1.2m in length x 1.3m width x 0.6m in height. It is a representative semi-sub platform, with a full scale mass of 25,570 tonnes.

Figure 2 - MARINET Platform in Deep Ocean Basin (Lir)

The mooring configurations used for testing are described in Table 1. A conventional heavy chain catenary mooring was included in testing as a baseline reference. This was optimised and tested with an LRD integrated into the catenary mooring. An Inclined Taut Mooring (ITM) with LRDs incorporated was also examined, as it is expected to offer the lowest risk profile and LCOE for FOW.

Each LRD is cylindrical, approximately 0.3m – 0.45m in length. At full scale, the catenary configurations have a mooring line radius of 852m, with the ITM systems having a radius of 355m. Two catenary systems with LRDs are tested, with the 155mm Catenary with LRD [B] system favouring load reduction compared to the baseline, while the 131mm Catenary with LRD [C] focuses on developing a more economical mooring system with less focus on mooring line loads. The ITM [D & E] systems present further economical gains for the mooring system, as well as lighter and smaller components, simplifying installation and recovery.

Eight wave conditions were run at each of the mooring configurations as described in Table 2. Four regular waves were used with different periods, to characterise the platform response. Four irregular wave states were tested on each configuration, each representing different real-world conditions as could be experienced in the North Atlantic. Sea state 5 with an 8m Hs is representative of the upper limit of turbine operation, and was run with a 250T equivalent turbine load to replicate the thrust from a 15MW turbine. Sea states 6, 7 and 8 replicate situations where turbines would be feathered, and so had a 100T equivalent load to account for the turbine drag forces. Seastate 7 represents a 50 year return period seastate for the west coast of Scotland, and seastate 8 represents a 50 year return period seastate for the coast of Clare, on Irelands west coast.

Table 1 - Mooring Configurations (Water Depth = 100m)

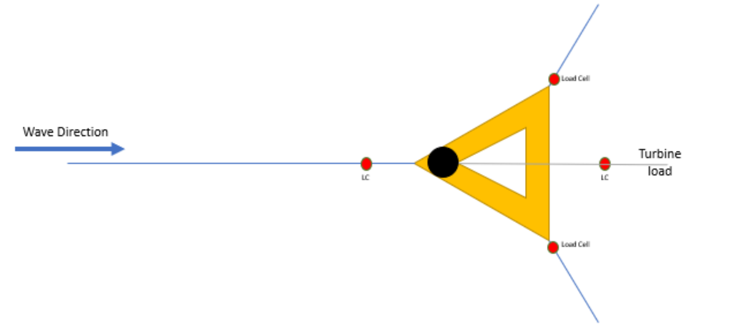
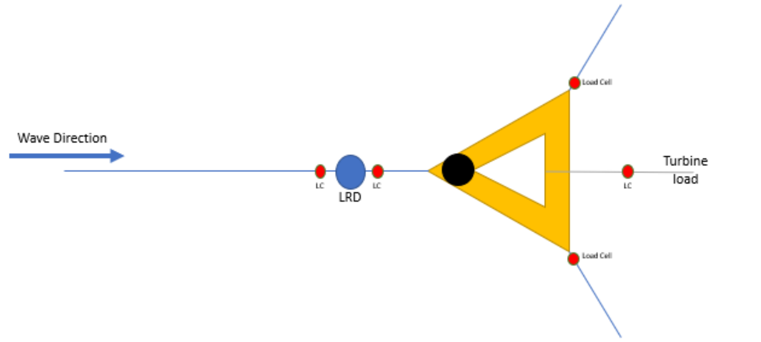
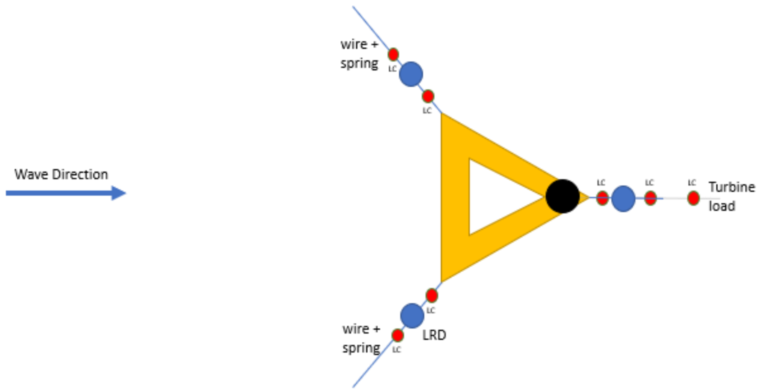
#	Description	Layout
A	**Catenary Baseline** Heavy Chain (155mm) without LRD	
B	**Catenary Baseline + LRD** Heavy Chain (155mm) with LRD	
C	**Optimised Catenary + LRD** Lighter Chain (131mm) with LRD	
D	**Inclined Taut –** Intermediate Modulus Inclined Taut System with 3 x LRD - Polyester	
E	**Inclined Taut** – High Modulus inclined Taut System with 3 x LRD - HMPE	

Table 2 - Sea States

#	Type	Hs [m]	Tp [s]	Gamma	Turbine Load [T]	Code
1	Regular	4	5	N/A	N/A	**REG1**
2	Regular	4	10	N/A	N/A	**REG2**
3	Regular	4	15	N/A	N/A	**REG3**
4	Regular	4	20	N/A	N/A	**REG4**
5	JONSWAP	8.00	12.60	2	250	**IRR1**
6	JONSWAP	12.9	15.99	1	100	**IRR2**
7	JONSWAP	15.5	19	1	100	**IRR3**
8	JONSWAP	17.8	19	1	100	**IRR4**

3 Results

3.1 Load Reduction

The measured loads from the tests show a load reduction for all mooring configurations when compared to the baseline. The peak load reduction is 48% for the case of the 1 in 50 year wave [IRR4] – the best performing mooring system in this regard is shown to be the Inclined Taut Mooring System with Polyester [D].

It should be noted the LRD was sized for the wave heights used in IRR3, with testing undertaken at IRR4 for research data on out-of-design conditions.

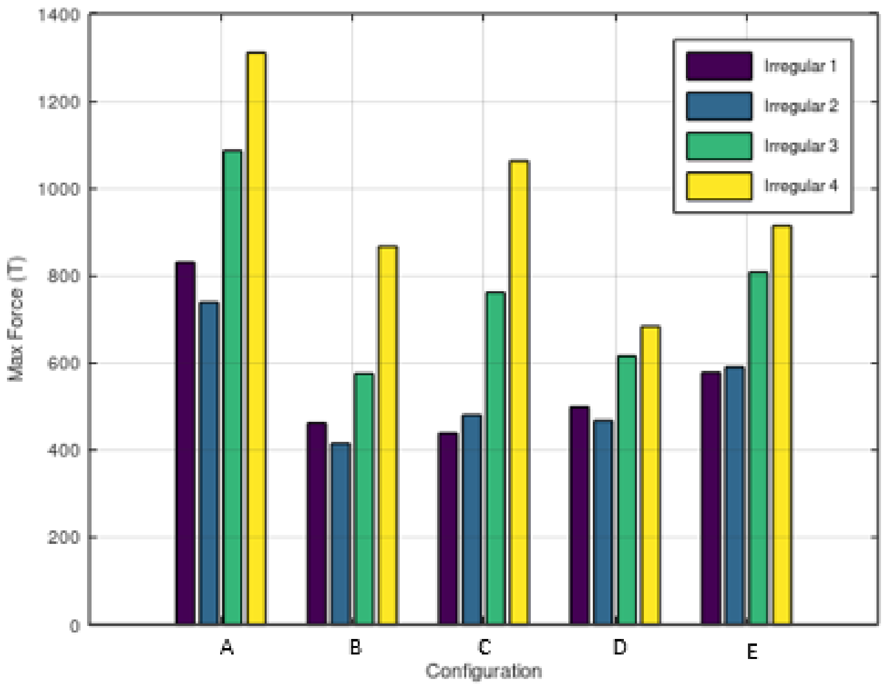


Figure 3 - Mooring Configurations - Peak Loads per Seastate

Table 3 - Mooring Load Reduction Results

	Mooring Configuration				
	[A] Baseline Catenary	[B] Baseline Catenary & LRD	[C] Optimised Catenary + LRD	[D] ITM - Polyester	[E] ITM - HMPE
Seastate	Load [T]	% Load Reduction from Baseline [A]			
IRR1	830.08	44%	47%	40%	30%
IRR2	738.29	44%	35%	37%	20%
IRR3	1086.2	47%	30%	43%	26%
IRR4	1311	34%	19%	48%	30%

3.2 Platform Motions

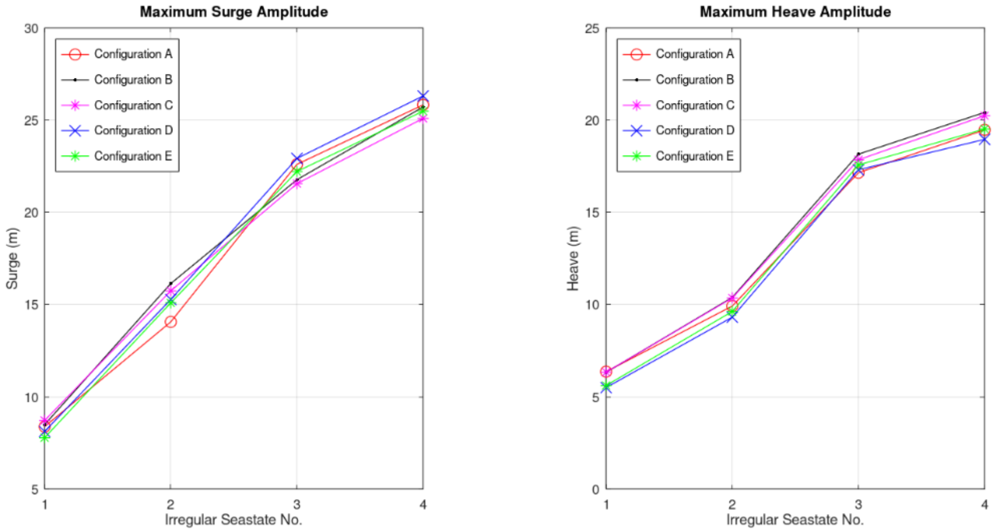


Figure 4 - Measured Platform Motions (Heave & Surge)

The platform responds similarly in heave and surge for all mooring configurations. Depending on the project requirements, if platform surge is a key design driver of the mooring system, this surge envelope can be reduced, with trade-offs against other mooring performance elements such as line tension. Surge optimisation may be desired due to dynamic cable requirements and can be delivered by a tailored LRD response curve.

3.3 Platform Accelerations

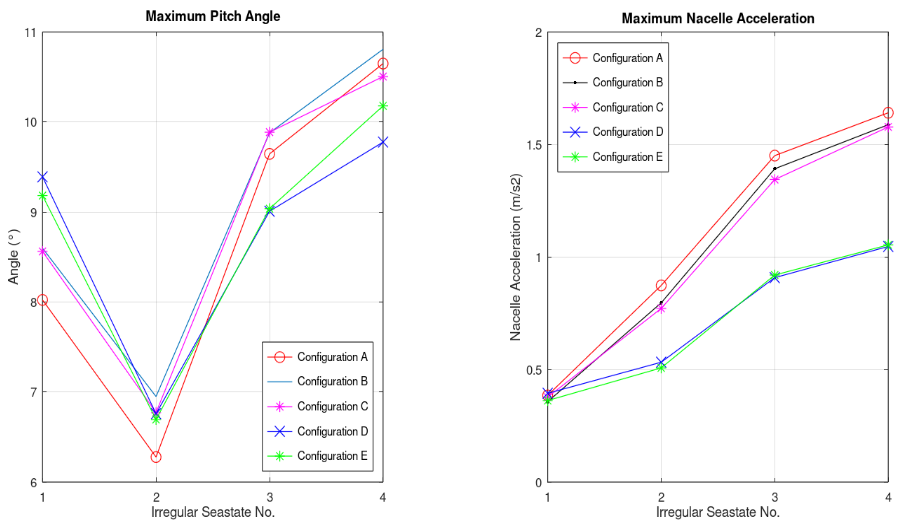
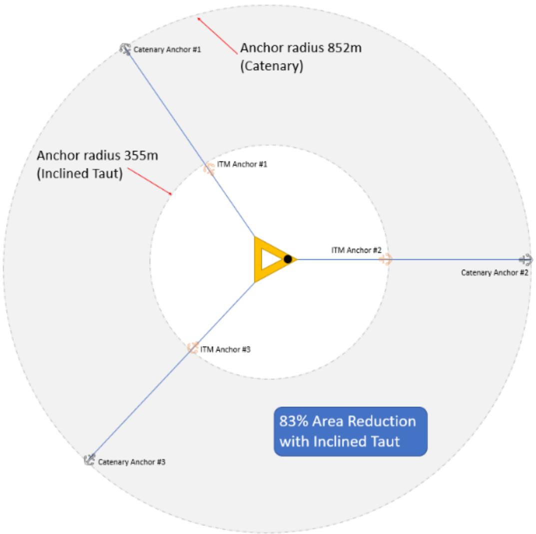


Figure 5 - Maximum Pitch and Platform Accelerations

Nacelle accelerations are reduced for the ITM systems. This may be a result of the softer combined response of the mooring and LRD system, lines, dampening some platform motion and slowing pitch oscillations and thus nacelle accelerations.

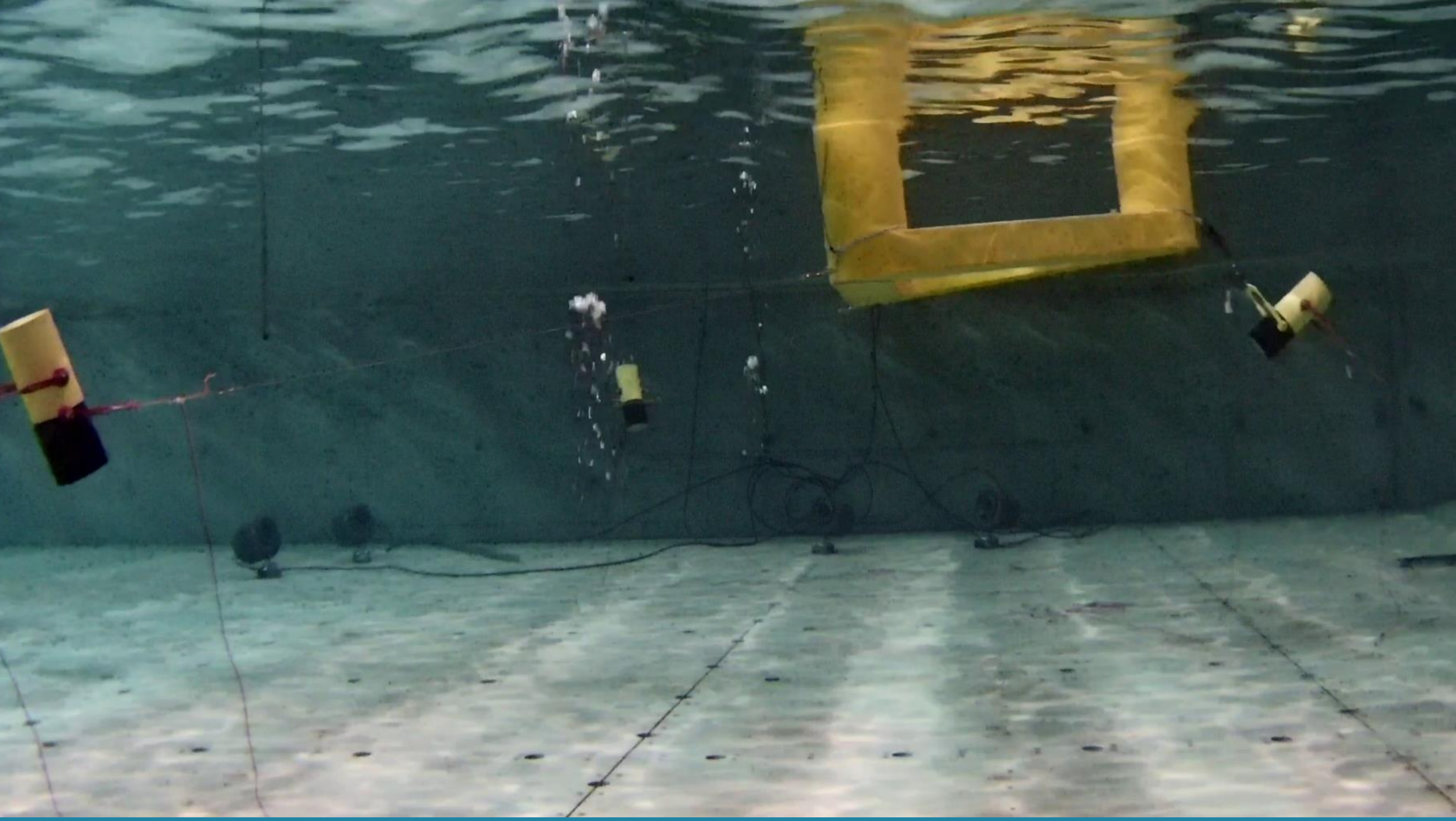
3.4 Platform Footprint



The original platform footprint required an anchor radius of 852m. This was reduced to 355m through the introduction of the ITM system. This is an 83% reduction in the area covered by the ITM system compared to the catenary system, reducing the scope and duration of seabed surveys required and likely resulting in more consistent seabed conditions for anchoring. The ITM system has no interaction between seabed and mooring lines, removing thrashing and the associated seabed or mooring line damage.

4 Conclusion

- The testing has provided further validation that the LRD delivers major load reduction across LRD integrated catenary and ITM configurations.
- The peak load reduction measured is 48% load reduction from baseline catenary load obtained by implementing the Inclined Taut Mooring System. This reduction was achieved during a 1 in 50 year storm event.
- The anchor radius was substantially reduced from 852m to 355m. The overall platform footprint area has reduced by 83% and there are no longer any mooring lines in contact with the seabed eliminating thrashing and the associated seabed / mooring line damage.
- Similar platform heave and surge response for catenary systems and inclined taut systems. This is a design choice made in specifying the test based on maintaining the baseline envelope. Further design choices can reduce excursion if required as identified by dynamic cable design. The reduced pitch and platform accelerations will also reduce loading on the dynamic cable.
- Nacelle accelerations are significantly reduced by use of ITM systems.



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